VOLUME 30 NUMBER 3

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THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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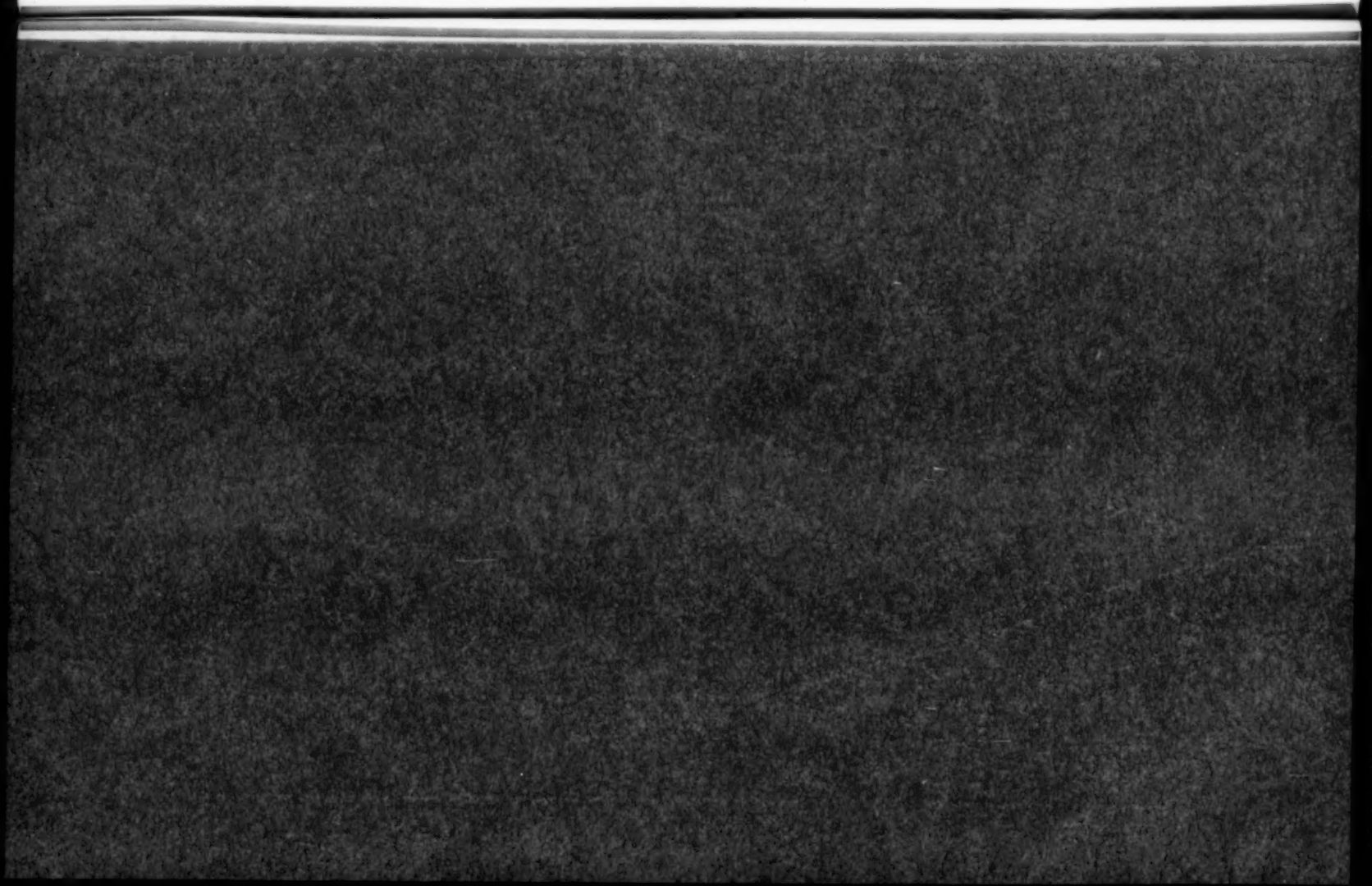

MARCH 1908 VOL. 30 No. 3

THE AMERICAN SOCIETY OF
MECHANICAL ENGINEERS

PROCEEDINGS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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On Promotion of Engineering Education

ALEX. C. HUMPHREYS — F. W. TAYLOR

On Government Advisory Board on Fuels and Structural Materials

P. W. GATES — W. F. M. GOSS
GEO. H. BARRUS

PROCEEDINGS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 30 MARCH 1908 NUMBER 3

THE March meeting of the Society will be addressed on Tuesday Evening, March 10, by Dr. Charles P. Steinmetz, Member A. S. M. E. and Past-President A. I. E. E. The subject will be "The Steam Path of the Turbine."

THE DETROIT MEETING

Plans for making the Semi-Annual Meeting in Detroit, June 23 to 26, one of the most instructive and enjoyable the Society has yet held, are in progress.

A symposium on the conveying of materials will be held, and members who desire to take part in that meeting are requested to send their articles to the Society as early as possible. Experience has proved that papers received early and published in the Proceedings well in advance of the meetings, receive the widest attention and discussion.

Articles published in the latest pre-convention issues, while often presenting very ably questions of interest to the Society, fail to elicit discussion because the members are not given sufficient time to read and study the data presented.

The Committee on Meetings can not guarantee to schedule for presentation at the Detroit Meeting papers accepted by them, when such papers are submitted later than April 15.

The outing feature of the Convention will not be neglected and excursions for pleasure and profit will be made to various places of interest in and around the city.

CONVENTION A. S. M. E. CONTEMPORANEOUS WITH S. P. E. E.

Contemporaneous with our meeting the Society for the Promotion of Engineering Education will hold their annual meeting in Detroit, June 23 to 26. Their headquarters will be in the same hotel, and so far as practicable, the sessions of the two organizations will be arranged so that opportunity will be given for members of each Society to attend the sessions of both.

Both organizations agreed upon the advisability of holding the convention late in June, considering, among other interests, that this time would permit of the attendance of professors and students, whose class work does not leave them free to attend a meeting earlier in the season.

FOREST PRESERVATION

THE WHITE HOUSE

WASHINGTON, February 17, 1908

My dear Sir: I am sending you herewith copy of a letter which on November 11, I addressed to the Governors of each of the several States relative to a proper conservation of the natural resources of this country and inviting the Governors, with their advisers, to meet in conference on this subject at the White House on May 13, 14 and 15 next.

I also enclose a copy of a letter recently received from the Executive Committee of the National Advisory Board on Fuels and Structural Materials, in which it is suggested that in bringing this matter before the people of the country, I invite the coöperation of the National Engineering Societies and other national organizations for research and development.

The suggestion is an excellent one; and I am led to believe that these organizations can render no more important service at this time than to develop among the people of this country a realization of the fact that these resources, upon which the future as well as the present welfare of the nation depends, are being exhausted rapidly, wastefully, and, in many cases, permanently.

I invite the coöperation of The American Society of Mechanical Engineers in properly bringing this matter before the people; and it gives me added pleasure to invite you, as the President of the Society, to take part in this conference at the White House during May 13, 14 and 15 next.

Sincerely yours

THEODORE ROOSEVELT

MR. M. L. HOLMAN, President, The American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City, N. Y.

A copy of the President's letter inviting the Governors of all the States and Territories to meet with him at the White House, May 13,

14 and 15, 1908, to discuss the question of the conservation of the nation's natural resources:

The natural resources of the United States were, at the time of settlement, richer, more varied, and more available than those of any other equal area on the earth. The development of these resources has given us for more than a century, a rate of increase of population and wealth without parallel in history. It is obvious that the prosperity which we now enjoy rests directly upon these resources. It is equally obvious that the vigor and success which we desire and foresee for this nation, in the future, must have this as its ultimate material basis.

In view of these evident facts, it seems to me time for the country to take account of its natural resources, and to inquire how long they are likely to last. We are prosperous now; we should not forget that it will be just as important to our descendants to be prosperous in their time.

Recently I declared there is no other question now before the nation of equal gravity with the question of the conservation of our natural resources and I added that it is the plain duty of us who, for the moment, are responsible to take inventory of the natural resources which have been handed down to us, to forecast the needs of the future and so handle the great sources of our prosperity as not to destroy in advance all hope of the prosperity of our descendants.

It is evident the abundant natural resources on which the welfare of this nation depend are becoming depleted, and, in not a few cases, are already exhausted. This is true of all portions of the United States; it is especially true of the longer settled communities of the east.

The gravity of the situation must, I believe, appeal with special force to the Governors of the States, because of their close relations to the people and the responsibility for the welfare of their communities. I have therefore, decided, in accordance with the suggestion of the inland waterways commission, to ask the Governors of the States and Territories to meet at the White House on May 13, 14 and 15 to confer with the President and with each other upon the conservation of natural resources.

It gives me great pleasure to invite you to take part in this conference. I should be glad to have you select three citizens to accompany you and to attend the conference as your assistants or advisers. I shall also invite the senators and representatives of the Sixtieth Congress to be present at the sessions so far as their duties will permit.

The matters to be considered at this conference are not confined to any region or group of States, but are of vital concern to the nation as a whole and to all the people. Those subjects include the use and conservation of the mineral resources, the resources of the land, and the resources of the waters in every part of our territory.

In order to open discussion, I shall invite a few recognized authorities to present brief descriptions of actual facts and conditions, without argument, leaving the conference to deal with each topic as it may elect. The members of the inland waterways commission will be present in order to share with me the benefit of information and suggestion, and, if desired, to set forth their provisional plans and conclusions.

Facts, which I can not gainsay, force me to believe that the conservation of our natural resources is the most weighty question now before the people of the United

States. If this is so, the proposed conference which is the first of its kind, will be among the most important gatherings in our history in its effect upon the welfare of all our people.

I earnestly hope, my dear Governor, that you will find it possible to be present.

Sincerely yours

THEODORE ROOSEVELT

January 2, 1908

THE PRESIDENT, *The White House.*

The matter of conserving the natural resources of this country in such manner that they will meet the future as well as the present needs of the nation, is one of such prime importance that it should receive the careful consideration of the people in every part of the country.

The members of the National Advisory Board on Fuels and Structural Materials have noted with interest your call for a conference on this subject at the White House in May next of the Governors of the several States, and the Executive Committee of this Board respectfully suggests that if it meet your approval, you write to the Presidents of each of the National Societies, of which a list is herewith appended, asking through them the coöperation of these societies, in the further consideration of this subject, and in the development of ways and means of stopping all unnecessary waste, thereby bringing about a proper conservation of these resources, without checking the growth of American industry.

Very respectfully,

[SIGNED] CHAS. B. DUDLEY, *Chairman National Advisory Board on Fuels and Structural Materials.*
President American Society for Testing Materials.

[SIGNED] CHAS. W. RAE, *Engineer in Chief, U. S. Navy.*

[SIGNED] ROBERT W. HUNT, *Past President American Institute of Mining Engineers.*

[SIGNED] W. F. M. GOSS, *Dean, School of Engineering, University of Illinois;*
American Society of Mechanical Engineers.

Members Executive Committee, National Advisory Board on Fuels and Structural Materials.

The Secretary has received communications from the American Institute of Electrical Engineers, The National Association of Cotton Manufacturers and various individuals urging the Society to coöperate in securing the preservation of forests.

Resolutions on Forest Preservation adopted by the Board of Directors of the A. I. E. E., January 10, 1908:

WHEREAS, The American Institute of Electrical Engineers recognizes that water powers are of great and rapidly increasing importance to the community at large, and particularly to the engineering interests of the country; and,

WHEREAS, The value of water powers is determined in great measure by regularity of flow of streams, which regularity is seriously impaired by the removal of forest cover at the headwaters with the resulting diminution in the natural storage capacity of the watersheds, this impairment frequently being permanent because of the impossibility of reforestation, owing to the destruction of essential elements of the soil by fire and its loss by erosion; therefore

Be it Resolved, That it is the opinion of The American Institute of Electrical Engineers that the attention of the National and State Governments should be called to the importance of taking such immediate action as may be necessary to protect the headwaters of important streams from deforestation, and to secure through the introduction of scientific forestry and the elimination of forest fires the perpetuation of a timber supply; and further

Be it Resolved, That the Committee on Forest Preservation be instructed to communicate these resolutions to all Members of Congress, and to the Governors of all the States.

Resolutions adopted by The National Association of Cotton Manufacturers.

At the Eightieth (Annual) Meeting of this Association held at Boston, Massachusetts, April 25–26, 1906, the following preamble and resolutions were adopted:

WHEREAS, The preservation of the forests at the head waters of streams rising from the Appalachian and White Mountains is an important element in the development of commercial enterprises, and would be of great benefit to the water powers on the rivers flowing from these mountains, and, therefore, to all the cities, towns and mills on these rivers.

Now, Therefore, Resolved, That the New England Cotton Manufacturers' Association, in annual meeting assembled thoroughly approves and indorses Senate Bill No. 4953, for the purpose of acquiring National Forest Reserves in the Appalachian and White Mountains, to be known as "The Appalachian Forest Reserve" and the "White Mountain Reserve" and further

Resolved, That this Association earnestly urges the New England Senators and Representatives in Congress to give Senate Bill No. 4953, their constant and vigorous support.

The Secretary would be pleased to receive advice from those members interested, for presentation to the Council at its meeting, March 10.

UNITED ENGINEERING SOCIETY REPORT OF TREASURER JANUARY, 1, 1908

NEW YORK, February 15, 1908.

To the Board of Trustees, United Engineering Society:

I beg to submit herewith the report of the Treasurer as of December 31, 1907.

Your attention is called to the fact that the resources and liabilities, receipts and disbursements statements cover all the financial transactions of the United Engineering Society from its organization up to December 31, 1907.

The income and expenses of operating the building during the whole operating period from December 15, 1906, to December 31, 1907, somewhat in excess of twelve months, are given.

Included in the expenses, amounting in all to $52 647.11, will be found an item entitled "Building Equipment" — (construction account). The expenditures under this item were not made for the operating expenses of the building, they represent a construction account, properly speaking, covering expenditures for furnishings and equipment of the building. The Founders' Agreement specifically provides for this class of expenditure under the provision that the Founders' Societies shall each be liable for a charge not to exceed $200 000 of principal, which shall include the land and building completed and ready for occupancy, together with the "Furnishings, equipment and personal property therein."

Certain details of equipment are yet to be supplied, and it is proposed in the near future to call upon the Founders' Societies for an assessment on their respective land and building funds to cover this item of building equipment. Such action would enable the item of $10 039.85 to be transferred to the income account and reduce correspondingly the assessment which it would be necessary to make on the Founders' Societies to cover the operating expenses for 1908.

The actual operating expenses for the period December 15, 1906, to December 31, 1907, have been		$33 126.41
or including Furniture and Fixtures, amounting to		1 307.41
we have a total operating cost of the building for the above period of		$34 433.82
This includes an expenditure for telephone service of	$1 174.76	
for which we are reimbursed by the occupants of the building, and also the cost of insurance premium for two years, only half of which should be charged to the 1907 operating account	1 087.24	

There should, therefore, be deducted from the 1907 operating account a total of.....		$2 262.00
making the actual net cost of operating the building for the period of twelve and one-half months, including repairs and renewals, but exclusive of depreciation and reserve allowance.....		$32 171.82
Or, for the year—exactly 12 months—.....	$30 884.94	

It will also be noted that in compliance with the provisions of the Founders' Agreement (Article 68) the Trustees have set aside, as a special fund to cover depreciation and reserve for 1907, an amount of $5000.

In the report submitted by Messrs. C. F. Scott, B. J. Arnold and Dr. S. S. Wheeler, under date of January 29, 1904, which was transmitted to the Founders' Societies at the time, it was estimated that the cost of operating the building would be approximately $27 000.39, exclusive of repairs and renewals and depreciation, which were estimated together at $2961 making a total then estimated of $30 000.

Attention is called to the fact that we have still available unoccupied space to the extent of the equivalent of one entire office floor, which, if occupied, would produce an increased revenue through assessments of approximately $11 000 per year.

While each Founder Society occupies and is assessed for one whole floor, some of this space would be available for other tenants should all the other office space become occupied.

The assessments paid by each of the Founders' Societies occupying one entire office floor were $10 000 per year. In addition to this each Founder Society bears its burden of interest charges amounting annually to $7000, a total cost of $17 000, exclusive of charges for any occupancy of the auditorium or meeting rooms.

At the present rate of assessments for office space, the Associate Societies pay for similar accommodations at the rate of only $8868 per year.

Even if it be assumed that the Founders' Societies alone should bear the pro-rated charges for the occupancy of the Library floors, their total assessments, on the basis of the Associates' assessment, should be only $14 780 per year, instead of $17 000, the amount they have actually paid the past year.

It should be noted that many of the Associate Societies did not move into their quarters until considerably after January 1, 1907, and the Income Account does not, therefore, represent a full year of occupancy.

It will be seen, therefore, that as long as there is unoccupied space in the building the burden which the Founders' Societies will have to bear will be considerably in excess of the corresponding assessments which are being charged to the Associate Societies. Attention is also called to the comparatively small use of the Auditorium as shown in the report of the Building Superintendent.

It is suggested that further efforts be made to induce other Societies to occupy the office space still available, and to secure a larger utilization of the Auditorium and Meeting Rooms. When such larger utilization shall be made of the exceptional facilities offered by our building, the burden of expense which the Founders' Societies are now called upon to bear will be notably reduced and the cost to them of their office facilities will be not greater than the rental of similar office space elsewhere, while the advantages accruing to each Society from joint occupancy of the building will be of inestimable benefit to every member.

Respectfully submitted

[Signed] J. W. LIEB, Jr.
Treasurer

UNITED ENGINEERING SOCIETY

Balance Sheet, January 1, 1908

ASSETS

Real estate, land	$540 000.00	
Real state, building	1 050 000.00	
Building equipment (construction account)	10 039.85	
Furniture and fixtures	1 307.41	
Accounts receivable	1 950.00	
Petty cash	500.00	
Cash, bank balance	6507.87	
		$1 610 305.13

LIABILITIES

Joint balance of mortgage (land)	$292 000.00	
A. I. E. E. payments in liquidation of mortgage on land	99 000.00	
A. S M. E. payments in liquidation of mortgage on land	99 000.00	
A. I. M. E. payments in liquidation of mortgage on land	50 000.00	
A. I. E. E. equity in building	350 000.00	
A. S. M. E. equity in building	350 000.00	
A. I. M. E. equity in building	350 000.00	
Building equipment (construction account)	10 039.85	

Furniture and fixtures	$1 307.41	
Depreciation and reserve fund	5 000.00	
Balance cash and accounts receivable	3 173.44	
Accounts payable	784.43	
		$1 610 305.13

UNITED ENGINEERING SOCIETY

Statement of Receipts and Disbursements up to December 31, 1907

RECEIPTS

Preliminary founders assessment	$24 000.00	
Account principal of mortgage	248 000.00	
Account interest of mortgage	47 098.86	
		$319 098.86
Refund account organization expense	4 696.18	
Refund account interest	46.55	
Refund account insurance	387.50	
Donation account dedication exercises	403.25	
		5 533.48
Assessment founders	29 999.97	
Assessment associates (offices)	9 134.22	
Assessment miscellaneous (meetings)	2 904.25	
Telephone and miscellaneous receipts	1 459.46	
		43 497.90
		$368 130.24

DISBURSEMENTS

Account principal of mortgage	$248 000.00	
Account interest on mortgage	58 798.86	
Organization expense	10 634.27	
		$317 433.13
Building equipment (construction account)	10 039.85	
Furniture and fixtures	1 307.41	
		11 347.26
Operating account (cash disbursements)	28 112.53	
Stationary and printing	1 890.26	
Insurance (two years)	2 339.19	
		32 341.98
Balance, cash in bank	6 507.87	
Petty cash	500.00	
		7 007.87
		$368 130.24

Operating income and expenses. Operating period December 15, 1906, to December 31, 1907

INCOME

Cash balance December 31, 1906	$7 199.21	
Assessment founders	29 999.97	
Assessment associates (offices)	9 408.55	
Assessment miscellaneous (meetings)	4 041.75	
Telephone and operating	1 997.63	
		$52 647.11

EXPENDITURES

Operating account	28 896.96	
Stationery and printing	1 890.26	
Insurance	2 339.19	
Total operating expenses	$33 126.41	
Building equipment (construction account)	10 039.85	
Furniture and fixtures	1 307.41	
Depreciation and reserve fund	5 000.00	
Balance (surplus on hand)	3 173.44	
		$52 647.11

GAS POWER SECTION

Pursuant to the call, members and others interested in the forming of a Gas Power Section assembled in the rooms of the Society at 7.30 p.m., February 11.

The meeting was called to order, and Dr. C. E. Lucke was chosen Chairman and Mr. H. H. Suplee, Secretary.

The Secretary of the meeting then read the rules for the formation of Professional Sections prepared by a special committee of the Society, consisting of Messrs. Hutton, Fernald, Humphreys, Suplee and Taylor.

These had been previously approved by the Council and the prospective members of the section also approved and proceeded to organize under them.

These rules were published in the February Proceedings. In substance they stated that a section must be officered by members of the Society and that all ordinary expenses will be borne by the Society. Extraordinary activities may be carried on as a section may elect, but at its own expense.

The intent of the Society is to give opportunity for any of its members to specialize without being obliged to form a new body. It further provides that persons not members of the Society may enroll

themselves as affiliates of a section. Thus the Society places at the disposal of sections or affiliated bodies the benefit of the organization of the Society.

An executive committee of five was chosen as follows, the Chair appointed Mr. Jesse M. Smith and Mr. Albert A. Cary, a committee to prepare nominations; Messrs. R. H. Fernald, G. Rockwood, F. H. Stillman, F. R. Low and H. H. Suplee were nominated, and no further nominations being offered, these names were put to a vote and unanimously elected.

The name of Dr. Chas. E. Lucke was then presented for President of the Section and he was unanimously elected to serve one year from December 6, 1907.

The meeting then adjourned to reassemble in the main auditorium where professional papers were presented and discussed as follows:

"A Continuous Gas Calorimeter," Dr. Chas. E. Lucke

This included a description of the Junker calorimeter, and of several modifications which had been made to render such devices continuous in their readings, followed by a description of the improved calorimeter invented by the author of the paper, in which the ratio of the flow of gas and water was maintained constant, enabling the calorific value of the gas to be determined at any moment by the simple inspection of temperatures. The addition of thermo-electric recording apparatus to the calorimeter enables it to furnish continuous records. The paper was illustrated with lantern slides.

"Recent French Experimental Gas Turbines," by H. H. Suplee

This was an exhibition of lantern slides of the 300 horse power gas turbine constructed by the Société des Turbomoteurs, of St. Denis, from the designs of Messrs. Armengaud and Lemale, as well as of the high-pressure multiple-turbine air compressor designed by Rateau for use in connection with gas turbine experiments.

"A Gas Electric Car," by H. G. Chatain

Mr. Chatain described the car built from his designs by the General Electric Company at Schenectady, and now undergoing tests. This includes an eight-cylinder gasolene V engine, direct-connected to a dynamo, furnishing current for electric motors on the trucks. The engine is of 125 horse power, and the car weighs about 31 tons, the engine having driven the car at a speed of more than 50 miles an hour.

"Gas Engine and Producer Guarantees," by Dr. Charles E. Lucke

In this paper Dr. Lucke called attention to the obscure and indefinite nature of existing specifications and guarantees given in connection with the efficiency and performance of gas producers and engines, quoting from a number of actual guarantees now used by various makers. He urged the importance of framing such documents so that there need be no opportunity for difference of opinion, or if such differences arise, the guarantee should be so framed as to render the points described to be of easy and positive determination.

After considerable discussion, in which the importance of greater definiteness in such guarantees was generally admitted and urged, it was moved by Mr. H. L. Doherty that the Chair be directed to appoint a committee, of which he (Dr. Lucke) should be a member, to examine the subject and report to the Section.

The meeting adjourned at 10.30 p.m.

The papers and discussions presented at the meeting will be published in April Proceedings.

THE SOCIETY REPRESENTED AT THE INSTALLATION AT THE UNIVERSITY OF ILLINOIS

The Society was invited by the Board of Trustees of the University of Illinois to send an official representative to attend the installation of the Dean of the College of Engineering. The Council appointed Mr. William Forsyth, Honorary Vice-President, as the official representative, and through his kindness, we are able to give the following report of the occasion.

Dr. W. F. M. Goss, Manager of the Society 1900–1903, and Life Member, was installed as Dean of the College of Engineering at the University of Illinois, on February 5. Upon this occasion Mr. Robert W. Hunt, Past President of the Society, made an address upon "The Value of Engineering Research," in which he discussed the waste of natural resources which has accompanied the development of America, and contrasted the conditions of iron and steel manufacture and coal mining of a comparatively few years ago with those obtaining today. While with the scant scientific knowledge of principles governing many industrial and manufacturing processes that was available 50 years ago large improvements had been comparatively easy; now, however, while the needs of further advance is imperative, the knowledge upon which the improvements depend can only be had by the most careful scientific research.

Mr. W. L. Abbott, Manager of the Society, and president of the

Board of Trustees of the University, made an address on "The Standing of the Technical Graduate in the Engineering Profession."

Mr. Willard A. Smith, editor of the Railway and Engineering Review spoke on "The Need of Graduate Courses in Engineering," and suggested that engineering research, which is becoming necessary, could be most properly done by the students in the graduate courses in engineering.

The formal address of the installation was delivered by Mr. Ira O. Baker, professor of civil engineering. His subject was "Some Significant Events in the Development of the College of Engineering." He gave the early history of the department of engineering at the University of Illinois.

In his installation address, Dr. Goss had for his subject, "The State College of Engineering." He emphasized the need for providing at our technical schools means for conducting original investigations. He cited the work of the University of Illinois in connection with the investigation of the properties of reinforced concrete as having large importance in the development of new building material. The failure of the Quebec bridge was also given as an instance in which the possession of adequate facilities for testing the correctness of the design of large structural steel members would have saved, not only the lives and money lost in that catastrophe, but our national prestige as well. He believed that the State colleges of engineering were the most effective agencies the State could provide for carrying on engineering research designed to secure those economic betterments which are dependent upon the discovery and proper application of natural laws by the engineer.

Several colleges, universities, engineering and railway societies and railway companies were represented among whom were Dr. W. K. Hatt, professor of civil engineering at Purdue University, representing the American Railway Engineering and Maintenance of Way Association; William McIntosh, superintendent of motive power of the Central Railroad of New Jersey, president of the American Railway Master Mechanics' Association; George N. Dow, general mechanical inspector of the Lake Shore and Michigan Southern, president of the Master Car Builders' Association; W. L. Abbott, chief operating engineer of the Chicago Edison Company, past president of the Western Society of Engineers; F. H. Clark, general superintendent of motive power of the Chicago, Burlington and Quincy, past president of the Western Railway Club; all of these representing their respective associations. William Forsyth, representing The American

Society of Mechanical Engineers; Morgan Brooks, representing the American Institute of Electrical Engineers; O. Stephenson, representing the Engineers' Club of St. Louis; C. F. Loweth, representing the Western Society of Engineers; Robert Quayle, Chicago and Northwestern Railroad, T. F. Barton and W. O. Moody, Illinois Central Railroad; C. B. Young and M. H. Wickhorst, Chicago, Burlington and Quincy Railway; A. F. Robinson, Atchison, Topeka and Santa Fé Railway; A. L. Kuehn, Cleveland, Cincinnati, Chicago and St. Louis Railway; A. F. West, Princeton University; H. C. Hoagland, Illinois Traction System; Professors C. H. Benjamin, M. J. Golden, C. A. Waldo, Stanley Coulter, and L. E. Endsley, Purdue University; J. J. Flather, F. S. Jones and W. H. Kavanaugh, University of Minnesota; W. H. Siebert, Ohio State University; W. D. Pence, University of Wisconsin; C. R. Richards, University of Nebraska; F. L. Bishop, Bradley Polytechnic Institute; G. F. Gebhardt, Armour Institute of Technology; L. E. Young, Missouri School Mines; E. C. Woodruff, Milliken University; Mrs. Laura B. Evans, and F. L. Hatch, Board of Trustees, University of Illinois.

THE LIBRARY

The members of the Founder Societies should impress upon themselves the large opportunity for information and research afforded by the library of the Engineering Societies.

It has a collection of 50 000 volumes of scientific and engineering works, and 450 current technical journals and magazines of Europe and America are readily accessible on the files of the reading room. The library is open every day except Sundays and holidays from 9 a.m. to 9 p.m. and librarians are constantly in attendance who will assist in finding information which the members and users of the library may not be able to locate.

A feature which is of continual service is a file of trade catalogues. An index to this file, both by subject and firm name, is kept to make the information easily accessible.

Members are requested to recommend the purchase of books not in the library which in their opinion would add to its reliable resources. Cards are kept at the librarian's desk for that purpose and such recommendations to purchase are immediately transmitted to the Library Committee for consideration.

Members should invite their friends in the profession to make use of the library. Such a storehouse of information should be largely

consulted and freely used for the advancement of science and engineering. The fact that it is a reference library free to all, should be generally advertised.

We quote from the American Machinist an article in regard to a recent valuable acquisition.

A VALUABLE ADDITION TO THE A. S. M. E. LIBRARY

The American Society of Mechanical Engineers is to be congratulated on the splendid addition to its library through the generosity of one of its best known members, Henry R. Towne. Some of the volumes date back to 1801 and the majority of them were printed previous to 1865, making it a notable collection of historical books, which oftentime contain more of value than we are apt to think and which would save us many thousand dollars in experiments if we but heeded their teachings.

One of the most notable examples of this is the book of C. Wye Williams on "Combustion of Coals," published in 1841, in which will be found all necessary details of a large number of tests which must have required endless patience and almost tireless energy, and which show practically every form of combustion improver and smoke consumer which has since been "invented" and used. It would be difficult to say how many thousand dollars of worthless experiments might have been saved had this book been studied first, but it would easily make a fortune that would satisfy most of us.

In the list published in the January *Proceedings* of the society, we find many notable books such as, "Evans on Steam," "The Locomotive Engine," by De Pambour; "Papers on Iron and Steel," by Mushet; "Combustion of Coals," by C. W. Williams; "Indicator and Dynamometer," by T. J. Main and Thos. Brown; "Cast and Wrought Iron," by William Fairbairn; "European Railways," by Colburn and Holley; "Papers on Mechanical Subjects," by Joseph Whitworth; "Engineering Precedents and Steam Engineering," by Isherwood, and "American and European Railway Practice," by Holley, with others, which are also valuable though perhaps not as well known in the mechanical world.

Collections of this kind are, or should be, safer in the care of such a library as this than in most private houses and we believe it is better for the owner as well as for the engineering public to have them cared for in this way. Any of us who have a few choice books, however, realize a hesitancy to part with them and Mr. Towne is to be commended for the generous spirit and broadness of view which prompted the donation. We feel that by this action he has placed us all in his debt—The American Machinist.

Authors are requested to contribute their own works and it is hoped that members will place in the library valuable books and objects of engineering interest. It is the aim of the Library Committee of the Founder Societies to make the library the most important technical library in the world, and their efforts should meet with a hearty spirit of coöperation from the members.

INVITATIONS TO THE SOCIETY

The Society wishes to acknowledge the courtesy of The American Institute of Mining Engineers in extending an invitation to the members to attend their Annual New York Meeting held February 18 to 20 in the Engineering Societies Building.

The following was the program of the meeting:

February 18, 8:15 p.m., "Electric Power in Steel Mills," by Mr. David B. Rushmore, Member A.S.M.E., Schenectady, N. Y.

February 19, 10. a.m. and 2. p.m. Physics of Steel. Discussion on Structure of Steel Ingots and their Mechanical Treatment. "The Work of the Testing Department at the Watertown Arsenal," by Mr. J. E. Howard, engineer in charge, and other papers.

February 20, 9 p.m., Reception.

The New York Electrical Society also invited the members of the A. S. M. E. to attend their meeting on the evening of February 28 in the Engineering Societies Building. The subject of the meeting was "Navigating the Air" and was treated by Mr. Augustus Post, Secretary of the Aero Club of America. It was illustrated by stereopticon views and models.

ANNOUNCEMENT

Under the direction of the Council the Committee on Society History has arranged to present the results of its investigations to the members of the Society.

The Preliminary Report will appear in the Proceedings of the Society from month to month, and thus enable the matter to be open to comment during its completion. It is especially desired that any member who may be in the possession of facts or information bearing upon the various points as they are thus made public will communicate with the committee, in order that the final and completed report may have the advantage of the collaboration of the membership at large.

HISTORY OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PRELIMINARY REPORT OF THE COMMITTEE ON SOCIETY HISTORY

CHAPTER I—Continued

23 The rules of the Society, as presented and adopted at the meeting of April 7, are here given in order to show the general system under which the Society was launched, and also to show that from the start it was determined that the papers presented before the Society should not, as in some other such organizations, be held closely confined to the Transactions, but that the author might give copies for publication to any reputable journal after reading before the Society.

RULES OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

As originally adopted at the Meeting for Organization, April 7, 1880

OBJECTS

ARTICLE 1 The objects of the AMERICAN SOCIETY OF MECHANICAL ENGINEERS are to promote the Arts and Sciences connected with Engineering and Mechanical Construction, by means of meetings for social intercourse, and the reading and discussion of professional papers; and to circulate, by means of publications among its members, the information thus obtained.

MEMBERSHIP

ART. 2 The Society shall consist of members, honorary members, associates and juniors.

ART. 3 Mechanical, Civil, Military, Mining, Metallurgical, and Naval Engineers and Architects may be candidates for membership in this Society.

ART. 4 To be eligible as a MEMBER, the candidate must have been so connected with some of the above specified professions as to be considered, in the opinion of the Council, competent to take charge of work in his department, either as a designer or constructor, or else have been connected with the same as a teacher.

ART. 5 HONORARY MEMBERS, not exceeding 25 in number, may be elected. They must be persons of acknowledged professional eminence, who have virtually retired from practice.

ART. 6 To be eligible as an ASSOCIATE, the candidate must have such a knowledge of, or connection with, applied science as qualifies him, in the opinion of the Council, to coöperate with engineers in the advancement of professional knowledge.

ART. 7 To be eligible as a JUNIOR, the candidate must have been in the practice of engineering for at least two years, or he must be a graduate of an engineering school.

(The term "Junior" applies to the professional experience, and not to the age of the candidate. Juniors may become eligible to membership.)

ART. 8 All members and associates shall be equally entitled to the privileges of membership, provided that honorary members, who are not also members or associates, and Juniors shall not be entitled to vote, nor to be members of the Council.

ELECTION OF MEMBERS

ART. 9 All candidates for admission to the Society, excepting candidates for honorary membership, must be proposed by at least three members, or members and associates, to whom they must be personally known, and be seconded by two others; the proposal to be accompanied by a statement in writing of the grounds of their application for election, including an account of their professional service.

ART. 10 All such applications and proposals received by the Council, up to 30 days before a regular meeting, shall, at least 20 days before such regular meeting, be passed upon by the Council. The Secretary shall, at least 20 days before the regular meeting, mail to each member and associate, in the form of a letter-ballot, the names of candidates recommended by the Council for election.

ART. 11 Any member or associate entitled to vote may erase the name of any candidate, and return to the Secretary such ballot enclosed in two envelopes, the inner one to be blank and the outer one to be endorsed by the voter.

ART. 12 The rejection of any candidate for admission as member, associate or junior, by *seven* voters shall defeat the election of said candidate. The rejection of any candidate for admission as honorary member by *three* voters shall defeat the election of said candidate.

ART. 13 The said blank envelopes shall be opened by tellers in a regular meeting, and the names of candidates elected shall be then announced. The names of candidates not elected shall neither be announced nor recorded in the proceedings.

ART. 14 Candidates for admission as honorary members shall not be required to present their claims; those making the nominations shall state the grounds therefor, and shall certify that the nominee will accept, if elected. The method of election in other respects shall be the same as in case of other candidates.

ART. 15 All persons elected to the Society, excepting honorary members, must subscribe to the rules and pay to the Treasurer the entrance fee and yearly dues, before they can receive certificates of membership. If this is not done within six months of notification of election, the election shall be void.

ART. 16 The proposers of any rejected candidate may, within three months after such rejection, lay before the Council written evidence that an error was then made, and if a reconsideration is granted, another ballot shall be ordered.

ART. 17 The Council shall pass upon application of juniors for membership, and shall order ballots upon such recommendations, in the manner hereinbefore described.

FEES AND DUES

ART. 18 The initiation fee of members and associates shall be $15, and their annual dues shall be $10, payable in advance, at the annual meeting; *provided*, that the persons elected at the meeting following the annual meeting shall pay $8, and persons elected at the meeting preceding the annual meeting shall pay $4, as dues for the current year. The initiation fee of juniors shall be $10, and their annual dues shall be $5, payable in advance. Any member or associate may become, by the payment of $150 at any one time, a life member or associate, and shall not be liable thereafter to annual dues.

ART. 19 Any member, associate or junior in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members, when in arrears for one year; *provided*, that such person may be restored to membership by the Council on payment of all arrears, or by reëlection after an interval of three years.

OFFICERS

ART. 20 The affairs of the Society shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, and a Treasurer, who shall be elected from among the members and associates of the Society at the annual meetings, to hold office as follows:

ART. 21 The President and the Treasurer for one year (and no person shall be eligible for immediate reëlection as President who shall have held that office, subsequent to the adoption of these rules, for two consecutive years); the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate reëlection to the same office at the expiration of the term for which he was elected. *Provided*, that, at the meeting for organization, the entire board of elective officers and managers shall be chosen, of whom the President, the Treasurer, three Vice-Presidents and three Managers shall serve until the first Thursday of November, 1881; three Vice-Presidents and three Managers shall serve until the first Thursday of November, 1882; and three Managers shall serve until the first Thursday of November, 1883. The holding for the several terms shall be determined by lot among them.

ART. 22 A Secretary, who may or may not be a member of the Society, shall be appointed for one year by a majority of the members of the Council at its first meeting after the annual election, or as soon thereafter as the votes of a majority

of the members of the Council can be secured for a candidate. The Secretary may be removed by a vote of twelve members of the Council at any time after one month's notice has been given him by a majority of its members to show cause why he should not be removed, and he has been heard to that effect. The Secretary may take part in any of the deliberations of the Council, but, if not a member of the Society, shall not have a vote therein. His salary shall be fixed for the time he is appointed by a majority vote of the Council.

ART. 23 At each annual meeting after the first, a President, three Vice-Presidents, three Managers, and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

ART. 24 The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Society; and the Council may, in its discretion, require bonds to be given by the Treasurer. At each annual meeting, the Council shall make a report of proceedings to the Society, together with a financial statement.

ART. 25 Vacancies in the Council may occur by death or resignation; or the Council, may, by vote of a majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings, or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed. *Provided*, that the said appointment shall not render him ineligible at the next annual meeting.

ART. 26 Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

ART. 27 No bill shall be paid for the Society, until it has been certified by the person authorized to contract it, and audited by the committee on finance.

ELECTION OF OFFICERS

ART. 28 At the regular meeting preceding the annual meeting, a nominating committee of five members, not officers of the Society, shall be appointed, and this committee shall, at least 30 days before the annual meeting, send the names of nominees to the Secretary, who shall at once mail the said list of names to each member and associate, in the form of a letter ballot.

ART. 29 In the election of Vice-Presidents, each member and associate may cast as many votes as there are Vice-Presidents to be elected. He may give all these votes to one candidate, or distribute them among more as he chooses. Managers shall be voted for in the same way.

ART. 30 Any member or associate entitled to vote may vote, by retaining or changing the names on said list, leaving names not exceeding in number the officers to be elected, and returning the list to the Secretary; such ballot enclosed in two envelopes, the inner one to be blank and the outer one to be endorsed by the voter. *Provided*, that no member or associate in arrears since the last annual meeting shall be allowed to vote until said arrears shall have been paid.

ART. 31 The said blank envelopes shall be opened by tellers at the annual meeting, and the persons who shall have received the greatest number of votes for the several offices shall be declared elected.

MEETINGS

ART. 32 The annual meeting of the Society shall be held in the city of New York on the first Thursday in November, at which a report of the proceedings of the Society and an abstract of the accounts shall be furnished by the Council; the Council may change the time of the annual meeting, and shall in that case give six months' notice to members and associates.

ART. 33 Two other regular meetings of the Society shall be held in each year, at such times and places as the Council may appoint. At least 30 days notice of such meetings shall be mailed by the Secretary to members, honorary members, associates and juniors.

ART. 34 Special meetings may be called, whenever the Council may see fit; the Secretary shall call a special meeting at the written request of 20 or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

ART. 35 Any member, honorary member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

ART. 36 Every question, which shall come before the Society shall be decided unless otherwise provided by these rules, by the votes of a majority of the members and associates present, provided there is a quorum.

ART. 37 At any regular meeting of the Society, 13 or more members and associates shall constitute a quorum.

PAPERS

ART. 38 The Council shall have power to decide on the propriety of communicating to the Society any paper which may be received, or to refer it back to its author for revision or amendment, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Society, shall, with the author's consent, be printed.

ART. 39 Intimation, when practicable, shall be given at a general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting.

ART. 40 The copyright of all papers communicated to, and accepted by the Society, shall be vested in it, unless otherwise agreed between the Council and the author. *Provided*, that the author shall in no case be deprived of his right to give copies of his papers for publication to any reputable journal, in which he may desire to see them printed after the same shall have been read, but the Society shall not be responsible for such unofficial publication.

ART. 41 The author of each paper read before the Society, shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, *provided*, that said copies are not intended for sale.

ART. 42 The Society is not, as a body, responsible for the statements of fact or opinion, advanced in papers or discussions, at its meetings; and it is understood

that papers and discussions should not include matters relating to politics or purely to trade.

AMENDMENTS

ART. 43 These rules may be amended, at any annual meeting by a two-thirds vote of the members present; *provided*, that written notice of the proposed amendment shall have been given at a previous meeting.

24 It is rather clear that these rules were drawn up in their original form by Mr. Holley, the other members of the committee finding his draft acceptable to them, while the memorandum, in Mr. Holley's writing, for the nominations of the first officers and managers of the Society corresponds, with but one or two exceptions, to the names actually chosen. The idea uppermost in his mind seems to have been the selection of men eminent in all the different departments of engineering work covered by the purpose of the Society, and his list specified distinctly the occupations of each candidate. Thus Mr. Worthington represented hydraulic engineering, Mr. Sellers, machine-tool design, Mr. Coxe, mining engineering, General Gillmore, military engineering, Mr. Shock, naval engineering, and in like manner the other members of the Council had their special departments of engineering work indicated.

25 In order to complete the organization without delay, the founder members were considered as having been proposed by the Committee on Organization, and were elected by a rising vote at the meeting, and the Treasurer, Mr. L. B. Moore, was instructed to serve the Council in the dual capacity as Secretary and Treasurer until a Secretary could be chosen.

26 After the adjournment of the meeting, applications for membership continued to come in, and prior to the first annual meeting the first catalogue was prepared by Mr. Moore, showing 163 Members, 17 Associate Members, and 9 Junior Members.

27 The first Annual Meeting of the Society was held at what was then the Union League Theater, at the corner of Madison Avenue and 26th street, New York City, on November 4 and 5, 1880, with 85 members present, this being the first meeting at which professional papers were presented.

The Council, by special resolution had determined to recognize the important work of Prof. John E. Sweet in the organization of the Society by inviting him to read the first paper presented before it, and upon this occasion Professor Sweet read a paper upon "Friction as a Factor in Motive-Power Expenses." This paper, which should have been given the first place in volume 1, of the Transactions, but

which actually appears as No. 12, in the numbered list of the Society's publications, gave a summary of the thought and effort which led to the design of the steam engine with which Professor Sweet's name has been identified during the lifetime of the Society. There is now upon the walls of the Society rooms a photograph of the first "straight line" engine, a souvenir of the result of the investigations described in this, the first professional communication to the American Society of Mechanical Engineers, at its first Annual Meeting.

28 The papers of the meeting, included in Volume 1, of the Transactions cover a wide range of thought and research, among them are found discussions upon steam engineering, machine shop practice, metallurgical processes and standardization. The state of the art at the time may well be understood when it is recalled that one of the papers was a plea for the general adoption of standard screw threads for bolts and nuts, while another was presented with the purpose of impressing upon mechanical engineers the importance of understanding the mechanical theory of heat.

29 In this volume also is included the paper upon the metric system by the late Dr. Coleman Sellers, a discussion which has frequently been made the subject of reference since.

30 It may be of interest to note that in his Presidential address, Dr. R. H. Thurston emphasized the fact that American iron furnaces were making 2 000 000 tons of pig iron per annum, this comparing curiously with the output of more than 25 000 000 tons for the year 1906, and also that he felt justified in stating that the compound steam engine had not yet definitely established itself as superior in economy to the single cylinder engine. He also remarked that "steam pressure has gradually and steadily risen since the time of Watt, until today 75 pounds per square inch is usual, and 90 pounds is often adopted." He noticed the fact that "iron was slowly but steadily and inevitably being displaced by steel," and also "that the feature of recent progress in engineering, which is attracting most attention, and awakening the most interest in the public mind, is the introduction of machine made electricity."

31 In the discussions it also appeared that the most powerful engines then projected were those of the steamship City of Rome. The latest development in transatlantic steamers at that time being the City of Berlin, upon which vessel, by the way, many of the members of the Society returned from Europe after the memorable trip of 1889. Both of these vessels are long out of service. These points are mentioned to show that an examination of the Transactions of the

Society, from the first volume of 1880, down to the present time, presents an illuminating record of the development of mechanical engineering.

32 During this period of the formation of the Society the evidence of the activity of the founders is everywhere evident. Both Mr. Holley and Mr. Worthington contributed to the discussions with their accustomed energy and ability, while many of the eminent engineers of the day took part, showing the immediate hold which the new Society had taken upon the members of the profession.

33 The meeting of November, 1880, closed the first year of the life of the Society, including the work of preliminary formation, permanent organization, and the full swing of professional operation. The close of the year found the Society, with about 250 members, and with a cash balance on hand of $3000, including initiation fees.

34 The work of the new organization attracted much attention from the technical press, both in the United States and in Europe, the papers and discussions being republished in whole or in part, and one of the objects of the association being thus attained—that of giving wide publicity to the work and researches of the members.

CHAPTER II

EARLY PROGRESS

35 The first year of the existence of the Society included three meetings and while two of these were devoted altogether to purposes of organization, the precedent seemed to call for three meetings in the following year. During the year 1881 meetings were held in May, at Hartford, Conn., in August, at Altoona, Pa., and the Annual Meeting was held in New York, in November.

36 Already death had begun to make inroads upon the membership and in December, 1880, one of the Founders of the Society, Mr. Henry R. Worthington passed away. Another of the Founders, Alexander L. Holley, who had been prevented by illness from presiding at the second meeting, at Hoboken, for the completion of the organization of the Society, had gone abroad and had there been so ill that his recovery was thought doubtful, but death claimed Worthington first, and although no name is appended to the sympathetic notice in his memory, appearing in the second volume of the Transactions, it is well known that this tribute was from the pen of Holley, the last communication from him to the Society.

37 The second volume of Transactions is more portly than its predecessor, containing as it does the papers of three professional meetings, and its contents demand some passing notice. During the discussions at the Hartford meeting the matter of having the papers printed and distributed to the members in advance of the meeting was brought up, and while positive action on this point was not taken at that time, the result was the adoption of the system of sending out the papers in advance of the meeting, a practice which finally developed into the publication of the present publication of the periodical journal of the Society.

38 In the discussion at the Hartford meeting there was also brought out an interest in the work of testing materials of construction which led to an active effort by the Society, in connection with other professional societies, to further the work of the Government Board in the testing of materials at the Watertown Arsenal.

39 Another matter discussed actively at that time, but yet awaiting effective action by the Society, was the indexing and digesting of technical periodical literature, a work which was afterwards taken up by the late Prof. J. B. Johnson, in connection with the Association of Engineering Societies, by the Engineering Magazine Digest, in the United States, by Science Abstracts in England, and by *Le Mois Scientifique et Industriel* in France.

40 It was at this meeting also that the Society passed, by a large majority, a resolution deprecating "any legislation tending to make obligatory the metric system into our industrial establishments." The principal discussions upon professional papers at the Hartford meeting related to the question of expansion-rates of steam in engine cylinders, this, and its accompanying subject, the most technical point of cut-off in steam engines, occupying an important portion of the Transactions.

41 The second meeting in 1881 was held at Altoona, Pa., with a registered attendance of 40. The general attractions at Altoona were, of course, the shops of the Pennsylvania Railroad Company, besides which there was a visit made to the works of the Cambria Company at Johnstown.

42 The Annual Meeting of 1881, being the second Annual Meeting of the Society held in the Turf Club Theater, New York, was noteworthy especially in that it marked the incorporation of the Society under the laws of the State of New York. The certificate of incorporation bears the date of December 24, 1881, but the proceedings had reached a stage which made it possible to announce in the report

of the Secretary at the meeting on November 4, that the incorporation might be regarded as an accomplished fact. At this meeting also it was announced that the now familiar badge, the four-leaved clover, bearing the initials A.S.M.E., had been adopted, and would be distributed to the members.

43 The origin of this badge may be a matter of interest and record in this place. The Society had employed Mr. Robert Sneider, an engraver and stationer, to prepare an ornamental die for use in connection with the printed matter relating to the Hartford meeting, and Mr. Sneider designed this symbol as an ornamental heading to the programs used on that occasion. The neatness and appropriateness of the design appealed to the Society to such an extent that the design was selected, without material change, as the badge of the Society, and as such it has been used to the present day, being recognized all over the world, as evidence of membership in The American Society of Mechanical Engineers.

44 At the time of the second annual meeting the membership of the Society had increased to 294 members in the various grades, and the interest in its work continued unabated.

45 At the election of which the results were announced at this meeting, Prof. R. H. Thurston was reëlected President and Mr. Lycurgus B. Moore was again chosen Treasurer, while the Council reappointed Mr. Thomas Whiteside Rae as Secretary of the Society. Mr. Moore, however, declined reëlection, and in consequence Mr. Charles W. Copeland was chosen Treasurer.

(To be continued)

OBITUARIES

ALBERT FRANKLIN KNIGHT

Albert Franklin Knight was born April 10, 1854, at East Greenwich, Rhode Island, and attended the home schools at Bristol and Providence.

From 1868 to 1875 he was an apprentice to the John L. Ross cotton mill, in the repair shop at Eagleville, Connecticut, and was made superintendent in 1875, holding the position until 1879. He was with B. B. and R. Knight, Providence, from 1879 to 1880; with the Bozrahville Company, Bozrahville, Connecticut, from 1880 to 1888, in both places acting in the capacity of superintendent of cotton mills. He built additional buildings and placed machinery, engines, boilers, etc. He was manager of the Canada Cotton Company, Cornwell, Ontario, from 1888 to 1889; superintendent of the Lonsdale Company, Ashton, and Lonsdale, Rhode Island, from 1889 to 1891; agent of the Amory Manufacturing Company, Manchester, New Hampshire, 1891 to 1898.

From 1898 to 1900, Mr. Knight was agent of the Berkshire Manufacturing Company of Adams, Massachusetts. Leaving there he entered business for himself, leasing and operating the Ray Cotton Mill at Woonsocket. Upon the expiration of his lease, he purchased the Farmers Cotton Mill at Farmesville, Massachusetts, and moved the machinery to a mill in Huntsville, Alabama. Afterward he engaged in the buying and selling of machinery and mill properties under the name of Providence Machinery Exchange. He was manager of this company at the time of his death, February 4, 1908.

OTHNIEL FOSTER NICHOLS

Othniel Foster Nichols, consulting engineer for the Department of Bridges, died February 4, 1908. He was born in Newport, Rhode Island, July 29, 1845. After preliminary training in the New York public schools he entered the Rensselaer Polytechnic Institute and graduated as a civil engineer in 1868. He was immediately employed as assistant engineer in the laying out of Prospect Park, Brooklyn, and in 1869 was appointed junior assistant of the first elevated railway in New York. In 1870 Mr. Nichols became assistant engineer

in the office of Cooper and Hewitt. The following year he went to Peru to construct the tunnel division of the Chimbote Railroad, and continued this work for four years. In 1878, after his return to the United States, he served as assistant engineer and superintendent for the Edge Moor Bridge Works, in the construction of the Metropolitan Railway, and was employed by the city as engineer in charge of the main drainage sewer for the annexed district. He then went to Brazil as resident engineer and attorney for the Madeira and Mamore Railway. He returned to the United States and reëntered the employ of the Cooper and Hewitt Company, serving two years as assistant engineer in the shops of the New Jersey Steel and Iron Company, and later as assistant to the president of the Peter Cooper Glue Factory. Subsequently he was appointed resident engineer of the Henderson bridge over the Ohio river and later, chief engineer of the Water Works Company of Westerly, Rhode Island. He resigned that position to become chief assistant engineer of the Suburban Rapid Transit Company of New York. Afterward he became chief engineer of the Brooklyn Elevated Railroad and also acted in that capacity for the Railway Construction Company and the Union and Seaside Elevated Railroad Companies. In 1892 and 1893 he was general manager of the Brooklyn Elevated Railroad. In 1895 he was appointed assistant engineer in the planning of the Williamsburg bridge, which office he held until 1903. He was then appointed assistant engineer in the Department of Bridges, and in 1904 was made chief engineer of the department, later acting as consulting engineer.

Mr. Nichols was a member of The American Society of Civil Engineers, The American Geographical Society, The British Institution of Civil Engineers, The Engineers' Club, president of the engineering department of the Brooklyn Institute and a trustee of the Brooklyn Collegiate and Polytechnic Institute.

ABEL G. GOLDTHWAIT

Abel G. Goldthwait was born April 17, 1837, at Sandgate, Vermont. He received a common school education and served a four years apprenticeship in mill work in the shops of a Mr. Buck of East Arlington, Vermont, after which he remained several years working in the machine and pattern shops.

About 1861 he was engaged in the mowing machine work in Troy, New York, and two years later was employed by Mr. William H. Tolhurst as pattern maker, but was soon promoted to the drafting

and designing departments, later was made superintendent of construction, and when the business was incorporated, he was elected vice-president. He was also its mechanical head.

While in this company he assisted Mr. Hartshorn in designing the Hartshorn window shade roller; he was designer for Mr. H. Stanley in making the first successful paper bag machine which took the paper in a roll and turned out bags, cut, folded, and pasted ready for use; he was principal designer of the Magee hot air furnace; he assisted in designing and constructing some of the first double-plate rim-braced, cast iron car wheels; he designed a saddle tree, the parts of which were made so as to be interchangeable, and orders for them from the Government amounted to 80 000; he was the designer of many of the paper box machines now in use; he successfully modified Mr. Holley's design of the converter for the Bessemer steel process; he designed most of the machinery used in the manufacture of paper collars in Troy, and drew the plans and superintended the construction of laundry machines for ironing both sides of a linen collar at one operation, and other laundry machines, among which was the Tolhurst Hydro-Extractor, which made possible the use of very large extractors with a miminum of vibration.

The first successful design of the universal car coupler, now used on all railroads in the United States was made by Mr. Goldthwait. He made many valuable improvements in the construction of magnetic ore separators, designing many valuable new features.

Mr. Goldthwait was elected a Member of the Society in 1892. He died November 17, 1907.

WILLIAM ROBERTS

William Roberts was born in Watertown, Massachusetts, March 25, 1835. After attending the Waltham Public Schools and the Auburndale Institute, he was apprenticed in 1851 to the Boston Manufacturing Company, Waltham, Massachusetts, as machinist, for three years, being made a journeyman in 1854. He worked at the Norfolk Navy Yard as journeyman until 1855.

On August 2, 1855, Mr. Roberts was appointed third assistant engineer for the United States Navy. He was with Commodore Perry on his expedition as assistant engineer on his flagship The Niagara, which opened the ports of Japan, and served on the Michigan, on the Lakes in 1856. In 1857 he was promoted to the office of second assistant engineer, served on the steam frigate Roanoke on the coast

of Central America, and was one of the officers of the steamer Fulton at the time of the capture of the fillibuster Walker in 1858. In July, 1859, he was made first assistant engineer and served on the Memphis on the Paraguay expedition. He resigned in September, 1859, and reënlisted, in response to the call for men, in April, 1861. At the attack on the forts and batteries at Pensacola Bay, in 1861, he was on the frigate Niagara, and in 1862 he was an officer of the steam sloop Housatonic when she drove two iron clad rams into the fort of Charleston.

In 1863, he was promoted to the office of chief engineer and was attached to the frigate Niagara, then undergoing repairs at the Charlestown Navy Yard. He served at sea and at navy yards as chief engineer and performed service at the Navy Department at Washington, until 1869.

In March of that year Mr. Roberts resigned his position in the Navy, and became associated with his father in the manufacture of paper in Waltham. He was also engaged as an expert in steam and hydraulic engineering. Under the firm name of John Roberts and Son, he carried on the paper business until the time of his death. Roofing paper and coarse wrapping paper were the principal products of the mill until the advent of asbestos paper, Mr. Roberts being the first to produce asbestos fireproof paper.

Among the societies of which Mr. Roberts was a member, are The Grand Army of the Republic, and The American Society of Civil Engineers. His death occurred December 28, 1907.

NEW BOOKS

Members are invited to donate copies of their works to the Library. This is a custom generally followed by members of an association, and in the case of this Society, with its wide membership among technical writers, its observance would result in a considerable development of the up-to-date resources of the Library.

NEW YORK STATE MUSEUM. EDUCATION DEPARTMENT. MEMOIR 8. INSECTS AFFECTING PARK AND WOODLAND TREES. By Ephraim Porter Felt, D.Sc. *New York State Education Department. Albany. 1905–1907. Vol. 1–2,* Cloth, 4to, 877 p., 70 plates.

NEW YORK STATE MUSEUM. EDUCATION DEPARTMENT. FIFTY-NINTH ANNUAL REPORT. *New York State Education Department. Albany. 1907. Vol. 2.* Cloth, 8vo.

STEEL WORKS ANALYSIS. By John Oliver Arnold and F. Ibbotson. *The Macmillan Company, New York; Whittaker & Company, London. 1907. Third Edition.* Cloth, 8vo, 468 p., $3.50 net.

Contents by chapter headings: The Steel Works Laboratory and its Appliances; Analysis of Steel and Wrought-Iron; Analysis of High Speed Steels; Analysis of Pig-Iron; Analysis of Spiegel and Ferro-Maganese; Analysis of Ferro-Chrome; Analysis of Ferro-Silicon; Analysis of Ferro-Aluminium; Analysis of Aluminium Metal; Analysis of Ferro-Tungsten; Analysis of Metallic Tungsten; Analysis of Ferro-Nickel; Analysis Metallic Nickel; Analysis of Ferro-Molybdenum; Analysis of Ferro-Vanadium; Analysis of Ferro-Titanium; Analysis of Ferro-Tantalum; Analysis of Iron Ores; Analysis of Manganese Ores; Analysis of Chrome Iron Ore; Analysis of Wolfram; Analysis of Scheelite; Analysis of Tantalite; Analysis of Refractory; Analysis of Fuels; Analysis of Slags; Analysis of Boiler Water; Analysis of Brass; Analysis of Bronze; Analysis of White Metals; Determination of the Specific Gravity of Steel; Estimation of Carbide of Iron; Determination of the Evaporative Power of Coal; Calculation of the Calorific Power and Intensity of Fuel; Tables of Typical Analysis; Tables of Atomic Weights; Percentage Compositions; Factors and a Comparison of English and Metric Weights and Measures and Thermometer Scales; Determination of Nitrogen in Steel.

INTRODUCTION TO THE STUDY OF ENGINEERING. By Henry H. Norris, M.E. *John Wiley and Sons. New York. 1907.* 8vo, v+404 p., 179 figures, cloth, $2.50 net.

Contents by chapter headings: Historical Development of Electrical Engineering; Fundamental Electrical and Magnetic Quantities; Materials of Electrical Engineering; Electric Circuits; Magnetic Circuits; Construction of Electric Circuits; Operation of Electric Generators; Transformers and their Applications; Construction and Operation of Power Stations; Electric Motors and their Applications; Electric Lighting and Heating, Electrical Measurements; The Transmission of Intelligence; Appendix.

EXPERIMENTAL ELECTRICAL ENGINEERING AND MANUAL FOR ELECTRICAL TESTING. By V. Karapetoff. *John Wiley and Sons. New York. 1908.* 8vo, xxxiv+790 p., 538 figures, cloth, $6 net.

Contents by chapter headings: Measurements of Resistances; Ammeters and Voltmeters—Construction and Operation; Ammeters and Voltmeters—Calibration; Indicating Wattmeters; Integrating Wattmeters; Reactance and Resistance in A. C. Circuits; Electrostatic Capacity; The Magnetic Circuit; Permeability Tests; Measurement of Core Loss; Photometry of Incandescent Lamps; Arc Lamps; Interior Illumination; Transmission Lines; Distributing Lines; Direct Current; Generators—Operating Features; Direct Current Motors—Operating Features; Direct Current Machinery—Efficiency and Losses; Direct Current Machinery—Opposition Runs; Transformers; Electrical Relations in Polyphase Systems; Alternators and Synchronous Motors—Operating Features; Alternators and Synchronous Motors—Commercial Tests; Rotary Converters; Induction Motors—Operating Features; Induction Motors—Special Study; Armature Windings; Alternating Current Wave Form; Electric Batteries; Switchboards; Controllers and Regulators; Electric Railway Work; Electric Heating and Welding; Elements of Telephony; Safety of Electric Plants.

THE METRIC FALLACY. By Frederick A. Halsey. THE METRIC FAILURE IN THE TEXTILE INDUSTRY. By Samuel S. Dale. *D. Van Nostrand Company. New York. 1904.* Cloth, 8vo, 231 p.

Contents by chapter headings: The Metric Fallacy; The Metric Failure in the Textile Industry; Appendix.

(Presented by the National Association of Manufacturers.)

MOVING LOADS ON RAILWAY UNDERBRIDGES. INCLUDING: DIAGRAMS OF BENDING MOMENTS AND SHEARING FORCES AND TABLES OF EQUIVALENT UNIFORM LIVE LOADS. By Harry Bamford, M.Sc., A.M. Inst. C.E. *The Macmillan Company, New York; Whittaker and Company, London. 1907.* Paper, 8vo, 78 p., $1.25.

Contents by chapter headings: Bending Moments and Shearing Forces in Beams; Diagrams of Bending Moments and Shearing Forces Due to Fixed Loads; Diagrams of Bending Moments and Shearing Forces Due to Moving Loads; Graphical Determination of the Maximum Bending Moment and Maximum Shear Due to a Train Load; Analytical Methods of Determining the Maximum Bending Moment and Maximum Shear Due to a Train Load; Diagrams of Maximum Bending Moments; Diagrams of Maximum Shear.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND. *Transactions. Vol. 50. 1906–1907. Glasgow. 1907.* Cloth, 8vo, 516 p., 20 plates.

NEW YORK RAILROAD CLUB. *Proceedings. Vol. 18, No. 2.* Paper.

THE GROWTH OF LARGE GAS ENGINES ON THE CONTINENT. By Rodolphe E. Mathot. *Excerpt from Minutes of Proceedings of the Meeting of the Institution of Mechanical Engineers, in Liége. June 21, 1905. Published by the Institution. London.* Paper, 76 p.

MOTEURS A COMBUSTION INTERNE ET MACHINES A VAPEUR. Par R. E. Mathot. *Extrait de la Revue de Mechanique. Paris. 1907.* Paper, 55 p., 2*f*.

REINFORCED CONCRETE IN FACTORY CONSTRUCTION. By Sanford E. Thompson. *Published by the Atlas Portland Cement Company, New York. 1907.* Cloth, 8vo, 249 p.

Contents by chapter headings: Factory Construction, Appendix; Fire Insurance on Reinforced Concrete, by L. H. Kunhardt; Design and Construction; Concrete Aggregates; Pacific Coast Borax Refinery; Ketterlinus Building; Lynn Storage Warehouse; Bullock Electric Machine shop; Wholesale Merchants' Warehouse; Bush Model Factory; Packard Motor Car Factory; Textile Machine Works; Forbes Cold Storage Warehouse; Blacksmith and Boiler Shop of the Atlas Portland Cement Co.; Details of Construction; Miscellaneous Buildings; Letters.

(Presented by the author.)

THE CONSISTENCY OF CONCRETE. By Sanford E. Thompson. *Reprint from Proceedings of American Society for Testing Materials. Vol. 6. 1906.* Paper, 8vo, 25 p.

(Presented by the author.)

SAND FOR MORTAR AND CONCRETE. By Sanford E. Thompson. *Bulletin No. 3. Association of American Portland Cement Manufacturers. Philadelphia. 1906.* Paper, 8vo, 13 p.

(Presented by the author.)

FORMS FOR CONCRETE CONSTRUCTION. By Sanford E. Thompson. *Bulletin No. 13. Association of American Portland Cement Manufacturers. Philadelphia.* 8vo, 24 p., paper.

(Presented by the author.)

REPORT OF THE RESULTS OF EXPERIMENTS AT JEROME PARK RESERVOIR TO DETERMINE THE LAWS OF PROPORTIONING CONCRETE. By William B. Fuller, Member A. S. C. E. *City of New York Aqueduct Commissioners. 1905.* 8vo, paper, 92 p., 25 tables.

(Presented by Mr. Sanford E. Thompson.)

JOURNAL OF THE IRON AND STEEL INSTITUTE. *Vol. 75, No. 3. 1907.* Cloth, 8vo, 620 p,

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS. SUBJECT-MATTER INDEX OF MINING, MECHANICAL AND METALLURGICAL LITERATURE FOR THE YEAR 1902. Edited by the Secretary, M. Walton Brown. *Published by the Institute. Newcastle-upon-Tyne. 1907.* 8vo, paper, 180 p., 42*s*.

MEMOIRES ET COMPTES RENDUS DES TRAVAUX DE LA SOCIÉTÉ DES INGENIEURS CIVILS DE FRANCE. *Bulletins of October and November, 1907. Paris. 1907.* 8vo, paper.

PROCEEDINGS OF THE ENGINEERING ASSOCIATION OF THE SOUTH. *Vol. 18, No. 4. October, November, December, 1907. Nashville, Tenn.* Paper, 8vo, 134 p.

TRANSACTIONS AMERICAN FOUNDRYMEN'S ASSOCIATION. VANADIUM IN CAST IRON. By Dr. Richard Moldenke. Paper, 8vo, 10 p.

BULLETIN OF THE BUREAU OF STANDARDS. *Vol. 4, No. 2. January, 1908. Department of Commerce and Labor. Washington. 1908.* 8vo, paper, 344 p.

ANNUAL REPORT OF THE CHIEF OF THE BUREAU OF STEAM ENGINEERING TO THE SECRETARY OF THE NAVY, FOR THE FISCAL YEAR 1907. *Washington, 1907.* 8vo, paper, 56 p.

UNIVERSITY OF ILLINOIS ENGINEERING EXPERIMENT STATION. *Bulletin No. 16.* 8vo, paper, 28 p.

A STUDY OF ROOF TRUSSES. By N. Clifford Ricker. *Urbana, Illinois. 1907.*

AMERICAN SOCIETY OF CIVIL ENGINEERS. *Proceedings. Vol. 34, No. 1. January, 1908.* Paper, 66 p.

INSTITUTION OF MECHANICAL ENGINEERS. *Proceedings. No. 3. 1907.* 856 p., 70 plates, paper, 8vo.

STATE DEPARTMENT OF HEALTH OF NEW YORK. *Twenty-Seventh Annual Report for the year 1906. Albany. 1907.* Cloth, 8vo 94 p.

COMPTROLLER OF THE CITY OF NEW YORK. *Annual Report for the year 1906. Vol. 1.* Half mor., 4to, 132 p.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

03 Wanted, firm to manufacture patented gas engine on a royalty or will sell outright.

04 A company located in New York City, having an engineering proposition of unusual merit and one which has received the endorsement of eminent engineers throughout the country, desires an aggressive and energetic party with capital to take an active interest in the business. The business is well established and is unlimited in its scope and will bear the most thorough investigation.

05 Engineer for large smelting company; must be familiar with Corliss engines and usual plant equipment, some experience in direct current dynamos. Salary $150 to $175 a month. Location Middle West.

MEN AVAILABLE

40 Mechanical engineer desires to represent a first-class line of machinery in New York City; has had large experience in designing, making and selling machinery and has a world wide acquaintance with mining and machinery men.

41 Cement engineer, with experience in both wet and dry process, wishes position in charge of construction and management of cement mill. Technical education; practical experience in this line.

42 Mechanical and electrical engineer, 14 years experience, power station design and for 14 months acting superintendent of power stations, one of the largest street railway systems in New England. At liberty April 1, desires superintendent of power or similar position; would open office in Boston as New England representative of responsible manufacturer.

43 Graduate mechanical engineer, with present company four years; thoroughly familiar with rod mill operation and construction, able to take full charge of such department, practical experience in blast furnace and steel mill construction and design.

45 Member, technical graduate, 16 years in charge of design of light and medium interchangeable machinery and the tools for its production, also plant construction and maintenance.

46 Member, at liberty May 1, desires responsible position, thoroughly practical, used to handling large work and getting results, 13 years in Chicago and district. Present salary, $4000 per annum.

47 Mechanical engineer, nine years experience as designer, superintendent, general manager and intermediary positions, will be open for engagement about August 1. At present general manager large automobile concern; specialty of systematizing, increasing production and reducing costs. Good executive.

48 Academic graduate of Vienna, having seven years of American experience, desires a position as chief draftsman or engineer of a steel company. Applicant is systematic, economical and possesses inventive ideas.

49 Mechanical engineer, successful as a practical inventor and constructing engineer, experienced in gas, refrigeration, air, steam and hydraulic engineering, etc. University graduate, practical machinist, 20 years experience in mechanical engineering, desires to make a change.

50 Member of 25 years experience conducting an office of his own in New York as mechanical engineer and patent solicitor, offers a portion, up to one-half, of his time in redesigning, developing and patenting special machinery or improving output in local manufactory.

51 Mechanical engineer, age 33 years, experienced in the design and construction of power plants and general factory engineering, desires permanent position as mechanical engineer or shop superintendent where energy and ability are required.

52 Member of the Society will be available for temporary engagement during the latter half of 1908. Can be of immediate service in executive work, calculation and design, testing and experimental work, inspection of boilers, engines, machinery, tools and supplies; mechanical engineering of power plants a specialty; speaks French and Spanish fluently.

53 Technical engineer, 33 years old, experienced in designing and erecting power plants, pumping plants and irrigation plants, heating system and general contracting engineering; best of references. Desires position with contracting or consulting work.

54 Mechanical engineer, thoroughly experienced in gas engine and automobile design, desires position as mechanical engineer or superintendent.

55 Mechanical engineer or assistant superintendent. Familiar with modern shop methods and practice, interchangeable manufacturing and limit gages; can handle successfully all classes of labor. Location, California, Colorado, or similar climate.

56 Member of the Society familiar with the engineering and metal working trades, is about to open office in Boston and would like to make arrangements to represent two or three concerns in the New England States.

CHANGES OF ADDRESS

AHRNKE, H. P. (Junior, 1902), care of J. R. Chapman, Esq., 71 Holland Park, London, W., England.

AUSTIN, William S. (1902; 1906), Mech. Engr., Westinghouse, Church, Kerr & Co., 10 Bridge St., New York, and 649 Prospect Pl., Brooklyn, N. Y.

BAEHR, William Alfred (1903), 4938 McPherson Ave., St. Louis, Mo.

BARBOZA, Arthur S. (1906), Rua Senador Pompeu 268, E. F. C. B., Rio de Janeiro, Brazil, S. A.

BLENCOWE, John (1900), Mgr., James Simpson & Co., Ltd., Newark-on-Trent, Nottinghamshire, England, and *for mail*, care of A. L. Raub, West Lafayette St., College Hill, Easton, Pa.

BUCKINGHAM, Henry H. (Junior, 1904), Hysham, Mont.

BUCKLER, Albert Hammond (Junior, 1905), 16 Third St. S. E., Washington, D. C.

BURGOON, Charles Eli (1907), Ch. Engr., U. S. Custom House, New York, and 35 Rugby Road, Brooklyn, N. Y.

CHANDLER, Sellers McKee (Junior, 1905), Pittsburg Valve and Fittings Co., Barberton, O.

CORNELIUS, Henry Robert (1888), Sales Mgr., Wisconsin Engine Co., 832 Frick Bldg., and Darlington Rd., Pittsburg, Pa.

DAVIS, Charles Ethan (1896), care of the American Locomotive Automobile Co., Providence, R. I.

DAVIS, Edwin Halsted (Junior, 1907), Ch. Draftsman, Davidson's Steam Pump Works, and *for mail*, Y. M. C. A., Bedford Ave. and Monroe St., Brooklyn, N. Y.

DE GAIGNE, Oscar Victor (Associate, 1907), 360 E. 62d St., Chicago, Ill.

FELTHOUSEN, John H. (1896), Hydr. and Mech. Engr., S. Morgan Smith Co., and *for mail*, Linden Ave. and West St., York, Pa.

FISHER, Henry Donald (Junior, 1907), Coal Dept., Arthur J. Little, 93 Broad St., Boston, Mass.

FLETCHER, James R. (1906), Supt., Yale and Towne Mfg. Co., and 187 Greyrock Pl., Stamford, Conn.

FLINN, Charles Forrest (Associate, 1905), Mech. Engr., 570 Old Colony Bldg., Chicago, and *for mail*, 6448 Washington Blvd., Oak Park, Ill.

GAY, Harry (Associate, 1907), Asst. Engr., N. Y. C. & H. R. R. Co., Electric Traction Dept., 1231 Grand Central Sta., and *for mail*, 400 Manhattan Ave., New York, N. Y.

GILLAN, Howard A. (Junior, 1907), Accumulatoren, Fabrik A. G., Hagen i/w., Central Bureau in Berlin, Germany.

GODDARD, Arthur L. (1903), Rockford, Ill.

GOLDINGHAM, Arthur Hugh (1907), De La Vergne Mch. Co., Foot East 138th St., and *for mail*, 457 W. 123d St., New York, N. Y.

HACKSTAFF, John D. (Junior, 1901), care of Hope Engrg. and Supply Co., 1012 New York Life Bldg., Kansas City, Mo.

HAMILTON, Alex. K. (Junior, 1900), Pres., M. H. Treadwell Co. of Ill., 510 Commercial Bank Bldg., Chicago, Ill.

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HELVEY, Geo. Stanley (Junior, 1904), Mech. Engr., Allis-Chalmers Co., First Natl. Bank Bldg., and *for mail*, 4259 Grand Blvd., Chicago, Ill.

HUTCHINGS, Clifford F. (Junior, 1907), Sprague Elec. Co., 527–531 W. 34th St., and *for mail*, 2441 Seventh Ave., New York, N. Y.

KAPY, Artturi A. (Junior, 1903), M. E., Government Expert for Farming Mchy., Patomaki Estate, Lahti, Finland.

KENT, Ellis C. (1889), Room 703, 120 Liberty St., New York, N. Y.

KLEIN, Arthur W. (Junior, 1903), Instr. in Mech. Engrg., Williams Hall, Lehigh University, S. Bethlehem, and 158 S. New St., Bethlehem, Pa.

LANE, Henry Marquette (1900) Editor, Castings, Caxton Bldg., and Secy., The Foundry Supply Asso., and *for mail*, 15, The Melrose, 1924 Prospect Ave., Cleveland, O.

LELAND, George B. (Associate, 1907), Genl. Supt., Stamford Gas and Elec. Co., and *for mail*, 127 North St., Stamford, Conn.

LOWE, Wm. Vose (1889; 1892), Engr. and Salesman, Hess Bright Mfg. Co., Philadelphia, Pa., and *for mail*, 8 Channing St., Worcester, Mass.

MITCHELL, William Clark (1901), Genl. Supt., The Dominion Iron and Steel Co., Ltd., Sydney, Cape Breton, Canada.

MUIR, John J. (1896), Mech. Supt., Bass Fdy. and Mch. Co., and *for mail*, 2221 Fairfield Ave., Fort Wayne, Ind.

NICKLIN, Ernest W. (1900; Associate, 1907), Mech. Engr., Atlas Engine Works, 430 Penobscot Bldg., and 310 Cadillac Blvd., Detroit, Mich.

PAINE, Henry E. (Junior, 1906), Euclid Heights, Cleveland, O.

PALMER, Arthur C. H. (1900), Asst. Engr., Queensland Railway, Brisbane, and *for mail*, Palmarosa, Hamilton, Brisbane, Australia.

POLLAK, Charles P. (Associate, 1901), The Wickes Boiler Co., Saginaw, Mich.

REID, Edward Snover (Junior, 1896), Engr., Northern Engine Wks., and 70 Pingree Ave., Detroit, Mich.

SCALES, Henry Jackson (Junior, 1907), Asst. Engr., Long Sault Development Co., Massena, N. Y., and Atlanta, Ga.

SCOTT, Seaton M. (1896; 1897), M. E., 55 Hawthorne St., Brooklyn, N. Y.

SEDERHOLM, E. T. (1889), Nordberg Mfg. Co., Milwaukee, Wis.

SHANTZ, Oliver S. (1900), Engr. and Salesman, 50 Hague Ave., Detroit, Mich.

SNYDER, Robert M. (Junior, 1890), Wilkinsburg, Pa.

STRANAHAN, O. A. (1900), The Westinghouse Mch. Co., 10 Bridge St., New York, N. Y.

SWASEY, Ambrose (1880), V. P., 1900–1902; Pres., 1904; V. P. and Treas., The Warner and Swasey Co., and *for mail*, 7808 Euclid Ave., Cleveland, O.

TOELLE, William E. (Junior, 1903), Supt., Baldwin Eng. Co., 107 W. 17th St. New York, N. Y.

VANDERBILT, Aaron (1880; 1884), Westhampton, N. Y.

VOGT, Axel S., (1884), Mech. Engr., Penna. R. R. Co., Altoona, Pa.

WADSWORTH, Frank L. O. (1903), Duquesne Club, Pittsburg, Pa.

WETMORE, Charles P. (1901), 1535 Leland Ave., Chicago, Ill.

WHITTEMORE, John R. (1902), San Isidro Cottages, Santa Barbara, Cal.

WILBUR, Ralston T. (Associate, 1907), Prof. of Engrg., Christian Brothers College; Resident Director, Mexico Portland Cement Co., and *for mail*, Box 622, St. Louis, Mo.

WORCESTER, H. E. (Associate, 1903), Mech. Engr., Revere Sugar Refinery, East Cambridge, Mass.

THE BY-PRODUCT COKE OVEN

By WILLIAM HUTTON BLAUVELT, SYRACUSE, NEW YORK
Member of the Society

Coke is the product of the dry distillation of bituminous coal, or in other words, coke is the solid residue remaining after bituminous coal has been heated in a closed, or partially closed, chamber until all of the volatile matter has been driven off. This volatile matter consists mainly of tarry matter, gas and ammonia, familiarly known as by-products. Both the quality and quantity of the coke and the by-products vary considerably with the quality of the coal. In this country coals similar to those from the Pocahontas region, containing from 16 to 18 per cent of volatile, stand at one end of the list, and produce the maximum yield of coke and the minimum yield of by-products. On the continent of Europe some coals are coked containing not more than 13 per cent of volatile matter. At the other end of the list stand the highly gaseous coals which contain as much as 38 or 40 per cent of volatile matter, and yield correspondingly small amounts of coke.

2 Good coke has a clearly defined cellular structure, with hard cell walls, the cells being small in size, and comprising about 55 per cent of the total volume of the coke, so that its bulk for a given weight is about twice as great as that of broken anthracite coal. The well developed cellular structure and the hard cell-walls are important in the use of coke for metallurgical purposes, and account for its superiority in blast furnace work, for example, over anthracite coal, which was formerly the principal blast furnace fuel. The cellular structure presents a large surface to the oxidation of the air, producing rapid combustion, while the firm cell-wall prevents crushing and maintains

To be presented at the Detroit Meeting (June 1908) of The American Society of Mechanical Engineers.

The professional papers contained in Proceedings are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present. They are issued to the members in confidence, and with the understanding that they are not to be published even in abstract, until after they have been presented at a meeting. All papers are subject to revision.

The Society as a body is not responsible for the statements of facts or opinions advanced in papers or discussions. C 55.

an open fuel bed. The specific gravity of a good quality of standard coke is about 1.7 to 1.9.

3 Many investigators have attempted to discover the substance which makes coal coke, with a view to determining why some coals will coke and others will not. A French chemist, Mr. Lemoine, believes that he has isolated this substance and gives it the name of "carbene." It is a black solid friable material tending toward crystallization, having the formula $C_{22}H_{14}O_5$. Experience has demonstrated that coals which are high in oxygen are usually deficient in coking qualities, and either will not coke at all, or produce a coke having a weak, friable structure. As will be shown later, many coals which produce very indifferent coke under ordinary conditions, by proper treatment can be made to yield a good metallurgical coke.

4 The production of coke in this country has grown very rapidly during the last decade, as is indicated by the following figures. The column showing the production from by-product ovens indicates that the growth of this branch of the industry has been fairly rapid, although several conditions have united to check it during the last few years.

PRODUCTION OF COKE, NET TONS

	Total	From by-product ovens	Percentage of by-product coke
1897	13 288 984	261 912	1.97
1898	16 047 209	294 445	1.87
1899	19 668 569	906 534	4.61
1900	20 533 348	1 075 727	5.24
1901	21 795 883	1 179 900	5.41
1902	25 401 730	1 403 588	5.53
1903	25 274 281	1 882 394	7.45
1904	23 661 106	2 608 229	11.02
1905	32 231 129	3 462 348	10.74
1906	36 401 217	4 558 127	12.52

In the above figures coke from gas works is not included.

5 A little study shows at once that the several types of coke ovens have sprung from three "root forms," the beehive oven, developed from the mound of the charcoal burners; the Coppée oven, with its vertical side heating flues, and long narrow coking chamber; and the Knab-Carvés, with the same narrow coking chamber and with horizontal side flues.

6 In the beehive oven the coal is coked in a flat layer, say 12 feet in diameter, and about 24 to 26 inches thick. In the retort oven the

coal lies in a long narrow chamber from 30 to 40 feet long, from 6 feet to 8 feet high, and from 16 inches to 22 inches wide. The essential distinction between the beehive and retort oven processes is that in the former the combustion which produces the heat for coking the coal, takes place within the coking chamber, above the coal. Air is admitted at the front door, and the products of combustion escape through a hole in the roof. In the retort oven the heat is generated by the combustion of gas in flues in the side walls: the heat passes through the walls into the coking chamber, but the products of combustion and the air are carefully excluded from the coking chamber. In the latter process, therefore, there is a true distillation of the coal, while in the former (the beehive oven) the admission of air materially changes the composition of the tars so that they are richer in the oils and paraffines, more like the tar produced from the Scottish blast furnaces, for example, where raw coal is used in place of coke. The admission of the air reduces the value of the tar products, as well as the quantity, and also destroys practically all the ammonia. The tar from the closed, or retort oven, on the other hand, contains considerable quantities of benzene, naphthalene, and anthracene, and other of the aromatic hydrocarbons which have given coal tar its great value in the manufacture of so many organic compounds, dyes, drugs, etc.

7 The retort oven may be arranged to recover the by-products from the distillation of the coal, or not, depending upon the market conditions and the quality of the coal coked. The coking process is essentially the same in both cases, except that when the by-products are not recovered the gas from the coal is led directly to the oven flues, while, when they are to be saved, the gas coming from the ovens is cooled and scrubbed to free it from the tar and ammonia, and is then returned to the oven flues. In both cases regulation is, of course, necessary, so that a suitable amount of gas is admitted to the flues to properly carry on the coking process.

8 The author has given, in some detail, in Mineral Industries, volume 4, page 215, the various steps of the development, from the earliest types of the beehive oven and of the various forms of by-product ovens in use in Europe. As our interest is rather in the by-product oven as it exists today in this country, this discussion will be confined to the types which have representatives here.

9 The beehive oven is, in general, familiar. Fig. 1 shows its ordinary form. As now built it is about 12 feet in diameter inside, and about 6 feet 9 inches high to the top of the domed roof. The

ovens are built in either single or double rows, banked together with masonry to prevent loss of heat. A charge of about six tons of coal is delivered by larry through a hole in the roof. Each charge of coal is fired from the heat remaining in the walls from the preceding charge; the air for combustion enters at the front door, the products of combustion escaping through the charging hole in the roof, producing the "pillar of cloud by day and pillar of fire by night" familiar to travelers in our coke regions. When the operation is complete, the coke is quenched with water by means of a pipe introduced through the front door, and after cooling, the coke is drawn either by hand or by machine, onto the wharf in front of the ovens, whence it

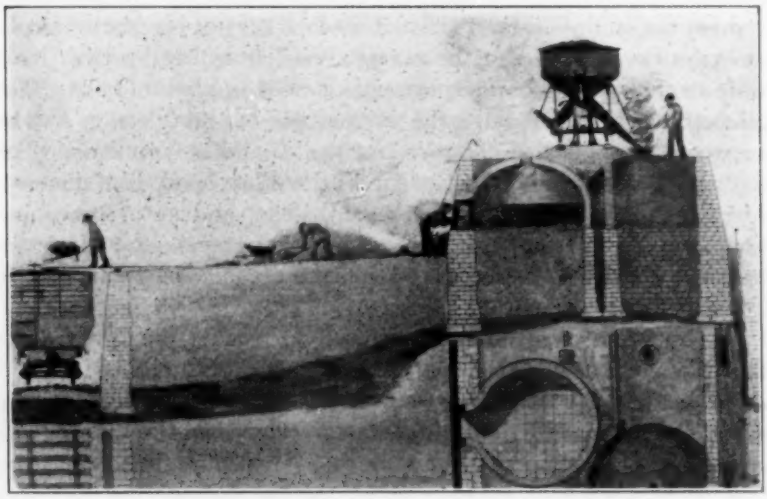

FIG. 1 SECTION OF BEEHIVE OVEN

is loaded into cars. The labor of drawing the ovens is the most expensive and laborious item connected with the operation. Much study has been given to devices for drawing the coke, and recently one has been developed which promises permanent success. This machine is shown in Fig. 2. It will be noted that it is arranged to travel on a track in front of the ovens, and when the oven is open and the arm thrust in, the coke is pulled onto the conveyor shown in the illustration, which automatically delivers almost the entire contents of the oven directly into the railroad car.

10 The coking process occupies from 48 to 72 hours, so that the output of a beehive oven is from 1.5 to two tons of coke per day. The

United States Geological report for 1905 gives 394.8 tons as the average output per active oven in that year. The beehive oven has been carried to its highest perfection in this country, and the above mentioned drawing and loading apparatus is only one of the comparatively recent improvements.

11 The use of silica brick in the construction of the beehive oven has become quite general, and is a distinct step in advance, notwithstanding that the general experience with silica brick, in regard to its rapid destruction when suddenly cooled, caused nearly all coke manufacturers to be very skeptical regarding its use until it had actually been tried.

FIG. 2 COKE DRAWER AND LOADER FOR BEEHIVE OVENS

12 In the present condition of our iron industry, subject as it is to extreme fluctuations, the beehive oven has certain advantages; it is quickly built and at relatively low cost, and the labor required for operation is of low grade. It may be put out of run at relatively small loss during the periods of industrial depression, and it can be started up again with ease after a shutdown. But with changed conditions the iron industry is becoming more stable; and moreover, the coals which were especially adapted for use in the beehive oven, are becoming more and more scarce, especially with the approaching exhaustion of the Connellsville field. There are very large deposits of coal in this country which are not well suited to the beehive oven, but which, under proper treatment will make excellent coke in the retort oven. In many sections of the country these deposits are the

natural source of supply for important metallurgical plants. In this respect the case is similar to some of the important iron districts of continental Europe, where the available coals may only be coked in the narrow retort oven, and where the beehive oven has long since entirely disappeared. It is especially in such cases that our attention is turned to the retort or by-product oven. This is essentially a long narrow firebrick chamber, from 30 to 40 feet long, from 7 to 9 feet high, and from 16 to 20 inches wide. It is closed at each end by doors lined with firebrick and usually there are from three to six holes in the roof through which the coal is charged. In the side walls and under the bottom of the chamber there are heating flues in which is burned a portion of the gas produced by the distillation of the coal, the heat passing through the firebrick walls into the coal. These heating flues are arranged sometimes vertically and sometimes horizontally. These ovens are built in blocks of from 25 to 50 or more. The distillation of the coal in this tightly closed chamber by heat from without, forms the essential characteristic of the retort oven.

13 The products of the distillation of the coal pass from the oven chamber through a hole in the roof to a large pipe, or main, extending along above the block. In some designs this main contains some water and the gas is forced through it in a manner similar to the hydraulic main of the gas works. The distillate, as it comes from the ovens, consists of a gas similar in general composition to ordinary illuminating gas, and it is loaded down with water and tar vapors and also carries ammonia. If the tar and ammonia are to be recovered from this gas, it is led to the by-product recovery building for treatment. If not, a proper proportion of the gas is returned to the oven flues and burned there with a properly regulated supply of air. The remainder, if any, is available for raising steam. The air is usually preheated either by regenerators, similar in principle to those of the Siemens furnace, or by transmission of the heat through thin walls of firebrick, commonly called recuperation. The heat for preheating the air is taken from the hot gases leaving the oven flues. In many plants these hot gases, after giving up a portion of their heat to the air, are passed under boilers for raising steam for operating the plant.

14 In the plants which recover the by-products, the gas coming from the main is treated in apparatus similar in general to that used in the manufacture of illuminating gas. The temperature is reduced gradually, so as to avoid shock of the gas with a consequent precipitation of naphthalene and the lighter hydrocarbons which form the principal illuminants of the gas, and is finally brought down to about

the temperature of the atmosphere. This work is done in large vessels cooled either by air or by water. There are a number of types of these coolers or condensers, a common form being a series of vertical cylinders containing tubes like a vertical boiler. Through these tubes water is circulated which cools the gas progressively as it passes from one vessel to another. During this cooling process most of the tarry matter and water vapor are thrown down, the latter carrying with it considerable quantities of ammonia.

15 After these condensers come the tar extractor and then the scrubbers, whose function is to remove the remainder of the ammonia and tarry vapor, and sometimes also the benzol and cyanides. The gas is drawn from the ovens and forced through these various apparatus by means of a rotary exhauster, operated either by a steam engine or electric motor. The ammonia is removed in a scrubber which may be of the "bubbling" or of the "rotary" type.

16 The "bubbling" type consists essentially of a vertical cylinder containing a series of compartments having inverted cups or bells with serrated edges dipping into water, so arranged that the gas bubbles through the water in fine streams, passing upward through the several compartments. Water is fed in at the top and runs out at the bottom as ammonia liquor containing from one-half to 2 per cent of ammonia. The rotary scrubbers are essentially large horizontal cylinders with a shaft running through them horizontally. On this shaft are arranged metal sheets, or brushes, or wooden slats so disposed as to offer the maximum amount of surface to the gas as it passes through the several compartments into which the cylinder is divided. The slow revolution of the shaft keeps the surfaces wet, the lower part dipping into water which partially fills the vessel. Water is fed in at one end and the liquor runs out at the other in the same manner as in the other apparatus.

17 The benzol and cyanide scrubbers are similar in construction, but instead of water, heavy oil of tar or petroleum is used to absorb the benzol, and for the cyanides, ferrous sulphate in an alkaline solution. After this treatment the gas is ready to be returned to the ovens for heating the flues, or to be sent out for use in gas engines, for illuminating gas, or for fuel, as market conditions determine. If it is to be used for illuminating purposes, it must be purified of its sulphur compounds in a similar manner to illuminating gas. When destined for this use it is also desirable to retain all of the illuminants. The removal of benzol is therefore omitted, and frequently advantage is taken of the fact that in the distillation of coal the early portion of the distillation

produces gas much higher in illuminants than the later portion. The gas piping from the ovens is therefore arranged, under these circumstances, so that the first portion of the gas coming off from each oven, say during the first six or eight hours of the coking process shall be kept separate from the remaining portion, lower in illuminants. In some plants the benzol is recovered from the portion carrying the lower illuminants, which is to be used for heating the ovens, and when this benzol is added to the richer portion, a gas is produced of much higher candle power than could be obtained from the same coal in the ordinary gas works, for example.

18 The tar and the ammonia liquor recovered from the various operations just described are collected in large tanks, and separated by the difference in their specific gravities. The tar is pumped to tanks for shipment, and the ammonia is sent to the ammonia distilling plant. This ammonia liquor, commonly called "weak liquor" contains as above, from one-half to 2 per cent of ammonia, also some of the lightest tar oils. The ammonia exists partly in the form of sulphate, chlorid and other fixed salts, from which the ammonia can be freed only by the admixture of lime, or some similar alkali, and the remainder as "free ammonia" in combination with carbonic acid, hydrogen sulphid, etc. When all of the fixed ammonia has been freed from the acid by the addition of lime, it is driven off from the liquor by boiling with steam, the condensed gases carrying a certain portion of water, to form the crude ammonia liquor of commerce. By the introduction of additional apparatus and the modification of the process of distillation, so as to separate the ammonia gas from the accompanying impurities, the aqua ammonia of commerce may be produced. Or the ammonia gas coming from the distillation apparatus may be absorbed in sulphuric acid, producing sulphate of ammonia which is described more at length elsewhere.

19 The recovery of benzol from the heavy oil used as an absorbent is effected by heating with steam in apparatus similar, in a general way, to that used for the ammonia. The benzol oils are driven off and condensed as crude benzol ready for purification, and the heavy oil is returned to the scrubber to be used again.

20 The modern by-product oven plant includes, among its more important mechanical problems, the delivery of the coal to the ovens and the removal of coke. The earlier installations in this country were small and the quantities of coal and coke handled did not justify the installation of much special apparatus, but with larger installations, consuming from 1500 to 3000 tons of coal per day, and

producing an equivalent quantity of coke, the handling apparatus has become one of the important features of nearly every plant. The location of these plants at the blast furnace, and the absolute dependence of the furnace on the coke produced, has made it necessary to store coal to prevent interruption of the operation from strikes, car shortages, etc. Also the location of some plants demands the storage, during the winter months, of coal which is brought by vessel in the summer. Then it is necessary to install unloading machinery. For example, an oven plant designed under the writer's direction a short time ago, is arranged with a capacity for unloading over 400 tons of coal per hour from vessels, and with apparatus for receiving this coal from the vessel and storing it at the same rate up to an amount of 300 000 tons. This apparatus will, at the same time, reclaim coal from this storage pile at the rate of 200 tons per hour and deliver it to the coal bins.

21 At this plant, among others, the engineering problem was further complicated by the necessity of mixing two coals of different composition in order to produce a coke of suitable quality. So the apparatus had to be arranged to store these coals separately, reclaim them separately, and bring them together in a mixture of proportions determined by the quality of the coals, and deliver this mixture to the oven bins. It was also necessary to grind the coal, in order to insure the best physical structure of the coke. The standard at this plant is that over 70 per cent must pass through a one-eighth inch mesh screen, and this work must be done at the rate of at least 200 tons per hour. Such undertakings present some very interesting problems in mechanical engineering, and upon their solution depends to a great extent the economical operation of the whole plant.

22 The operation of charging the ovens is a very simple one. The coal, prepared as described above, is delivered in bins above the ovens and drawn into a larry or car which runs over the top of the oven blocks, operated by a motor. This car is arranged with suitable chutes, and on opening the charging holes on the tops of the ovens the coal is allowed to run in and fill the oven chamber. These charging holes are then immediately closed, and the top of the coal is levelled off by means of a reciprocating ram, operating through one of the doors at the end of the oven. This leveling produces sufficient space for the gases to escape and reach the exit pipe, and also to provide for the swelling of the charge which usually takes place during the coking.

23 When the gases have been driven off from the coal, which

requires a period of from 18 to 30 hours, depending upon the coal and the oven, the doors at each end of the oven are opened, and the mass of coke is pushed out by a ram, operated by steam or electricity. This ram travels up and down in front of the ovens as required, and usually carries the leveling device above mentioned. By this method the coke is discharged in a few minutes, and the oven is ready for another charge, which is dropped in as soon as the doors are closed.

24 The coke, on discharging, must be quenched. The old way, and the one largely employed in Europe still, is to spread the hot coke on a brick pavement and water it with a hose. This does not usually give the best results, however, as the coke is blackened and frequently is made too wet. A number of devices have been developed for quenching, with varied success. In one, the coke is run into a tight firebrick chamber and water is admitted, the pressure of the steam generated driving the water throughout the different parts of the mass. In another plan, the coke is pushed out into a car 40 feet long and 10 feet wide, having an inclined bottom so arranged that by drawing the car along as the coke is pushed out it is distributed in a uniform layer, and is then quenched by a heavy stream of water, which is applied as soon as the coke reaches the car. Another device is in the form of a box-shaped frame, built up of water pipes so arranged that the coke is pushed out through it and quenched by a shower of water forced through perforations in the pipes—a sort of needle bath.

25 After quenching, the coke is delivered either into railroad cars or is carried directly from the original quenching car to the blast furnace bins, or to a sorting and picking plant, in case the product is to be sold for foundry coke. In this picking plant the coke is delivered from a small hopper onto the picking belt, where the black ends are removed, as is the custom in preparing foundry coke, and the small pieces are screened out, the coke being delivered to the car without any handling except of the rejected pieces.

26 All of this work was formerly done by hand, and the difficult quality of the material and the severe requirements of the market required the development of some special apparatus in order to accomplish the results mechanically, with low repairs and good efficiency.

27 With this general use of machinery, of course, the power plant becomes an important part of the installation, since, in some installtions, at least, all the apparatus and machinery are electrically driven.

28 Consumption of power in a plant of by-product coke ovens, of course, depends very much on the arrangement of the plant, and especially upon the conditions under which the coal and coke have to be handled. The following is the distribution of power consumed at one plant coking about 1500 tons of coal per day. The figures represent the average daily consumption in kilowatt hours. Of course, many of the operations, such as pushing and charging the ovens, are very intermittent.

	Kw-hr.
Handling coal to and from storage pile	450
Coal conveyors	900
Crushing and pulverizing coal	1130
Gas exhausters	1280
Rotary scrubbers and pumps in by-product recovery plant	1250
Pumps handling ammonia liquor	255
Pushers	684
Coal charging	168
Coke handling	1440
Pumping water	45
Lighting	730
	8332

29 Some special problems in design arise on account of the large requirements of steam for the distillation of the ammonia and other by-products. On this account a simple type of engine, operating under (say) 10 to 15 pounds back pressure, presents strong arguments for favor in comparison with more efficient engines. The use of the exhaust steam for distillation makes available the latent heat in the steam, as well as the sensible heat down to the temperatures at which the waste liquors are discharged. So that while by this method only 20 per cent of the heat in the steam is consumed in the engine, the remaining 80 per cent becomes available for the work of distillation. The steam consumption in such an engine is about 45 pounds per horse power. But when the exhaust steam is needed for distillation it is hard to equal the economies of this combination as compared with other types of steam engines, or even gas engines, combined with the use of live steam for distillation.

30 In addition to the problems of handling materials and the development of the mechanical appliances about the plant, which have been special features of the growth of the by-product oven in America, much progress has also been made in the oven itself. Although this retains its original form, the size and coking capacity

have been much increased. The earliest retort ovens in this country had a cubical capacity of 220 cubic feet, and had an average coking capacity of 4.4 tons of coal per 24 hours. Some of the ovens of today have a capacity of 430 cubic feet, or more, and coke about twelve tons of coal per day. Experimental installations are operating satisfactorily having an output materially above this figure.

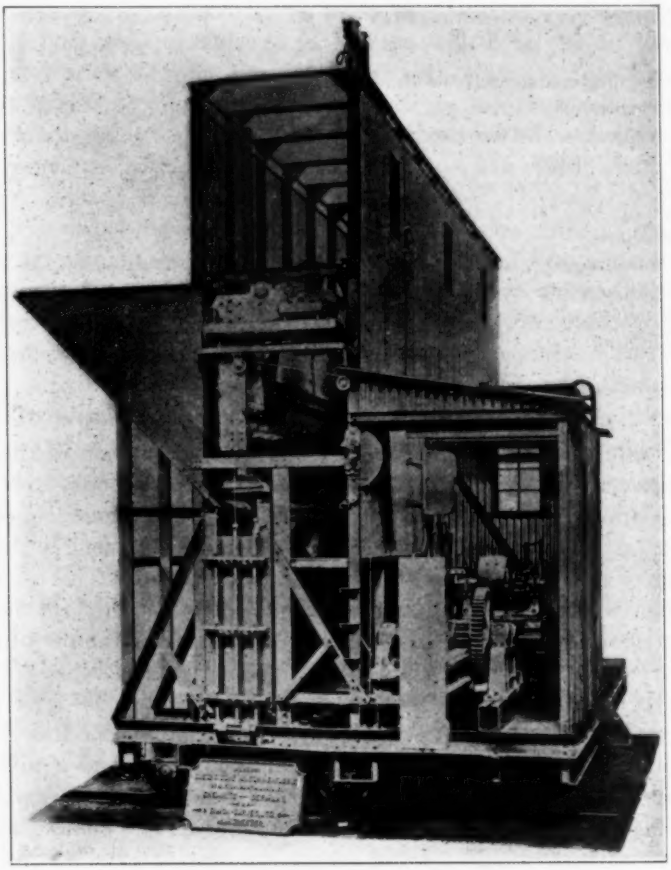

FIG. 3 COMBINED COKE STAMPER AND COKE PUSHER

31 Among the mechanical devices connected with the retort oven is the stamping machine. This machine, illustrated in Fig. 3, represents one of the successful German machines. This machine has been used largely in Europe, but only to a small extent in America.

It is used for the purpose of compressing the coal into a cake before charging into the oven. Many coals, on account of their composition, do not produce a coke of satisfactory physical structure by the ordinary methods of treatment, but when they are compressed into a cake, the physical structure of the coke is very much improved.

32 The process is in principle a simple one. A box or form is provided, slightly smaller than the oven chamber. This box is filled with coal, and during the process of filling the coal is compressed by heavy stamps traveling back and forth the length of the box, so that there is a reduction of volume of from 20 to 25 per cent, as compared with the loosely charged coal. The coal is dampened before stamping, and it is not difficult to form a cake having sufficient strength to permit of being pushed into the oven. Besides the improved quality of the coke, the output of the ovens is at many plants increased by about 10 per cent, and in some cases the managers state that they prefer this method of charging coal into the oven, even aside from its effect on the quality of the coke. The illustration shows a pusher combined with the stamping machine, so that the whole apparatus travels up and down together in front of the ovens, the coal being stamped in transit.

33 Five different types of by-product recovery ovens have been built, or are building in this country. One of these, the Newton Chambers, is an English adaptation of by-product recovery to the beehive oven, but the plant which is the only American representative of this type of oven has been out of run for some time. This system consisted essentially of a series of vertical cast iron U-pipes, arranged to receive the gases from the beehive oven and condense out the tar and ammonia vapors, by cooling with air or water, the scrubbed gas being returned to the oven, which was heated partly by the flues underneath, and partly by combustion in the upper part of the chamber containing the coal. As pointed out before, this method cannot but give low yields of ammonia and tar of inferior quality.

34 The four types of by-product ovens in operation and under construction in the United States are all of the retort oven type, and have all been developed from the original types of the Coppée, or Knab-Carvés designs. Of these there are eleven plants of the Otto-Hoffman and the United Otto type, 13 plants of the Semet-Solvay type, three plants of Rothberg ovens, and one plant of Koppers ovens, making a total of 28 plants or 4763 ovens. Detailed descriptions of these ovens having appeared elsewhere, I shall confine myself to a statement of the distinguishing points of the several systems.

35 The accompanying illustration Fig. 4 shows a typical United Otto oven plant in cross section. The oven is supported on steel girders resting on concrete piers. It is of the vertical flue, or Coppée type; that is, the gas is burned in a series of vertical flues arranged in the side walls between the oven chambers. The gas for heating the flues, which has been scrubbed and cooled in the by-product plant nearby, is delivered into the main combustion flue, both at the end of the oven and below in the gas pipes shown. The products of combustion pass into one of the regenerative chambers shown, thence to the stack, and the air is preheated in these chambers, on the principle of the familiar Siemens regenerative furnace. The currents

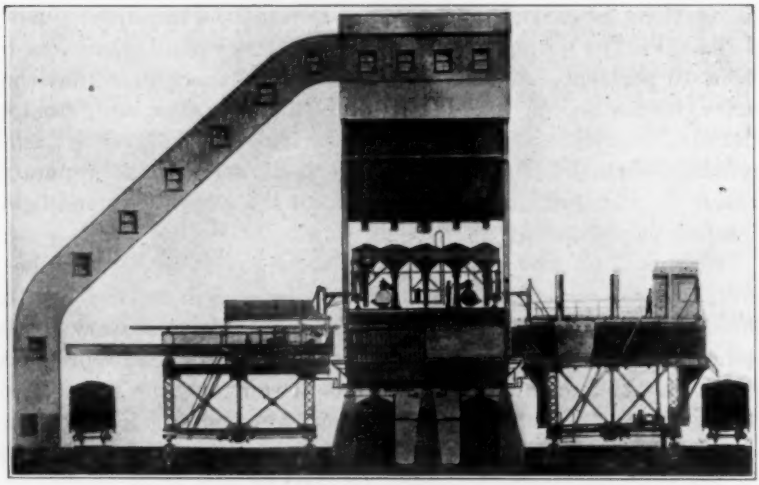

FIG. 4 SECTION OF UNITED OTTO OVEN

of gases and hot air are reversed at suitable intervals. During each of these periods the gases pass upward through one-half of the oven flue system, and downward through the other half, their path being reversed at each reversal of the regenerator valves.

36 The Semet-Solvay oven shown in Fig. 5, is a development of the Carvés type. Its salient feature is the horizontal flue system with strong middle walls which support the roof structure and the additional loads of charging larry, etc. The horizontal flue system is heated by means of gas introduced into the ends of all but the lowest flue. At each admission it meets with air for combustion which has been preheated by the escaping gases through the thin

walls of the "recuperator" arranged below the oven. The horizontal flues with the multiple gas admission admit of very accurate control of the heat and of its even distribution throughout the coking chamber. The main object of the central division wall above mentioned is the prolonged life of the oven structure, which results from taking the weight off of the thin and highly heated flues, and it also permits repairs to be made to any oven without shutting down any of the adjacent ovens.

37 The Rothberg oven is of the horizontal flue type, but more like the Huesner oven which has been developed in Germany, in that is has only one flue system between each coking chamber. This flue system is divided in the center by a vertical wall, forming two com-

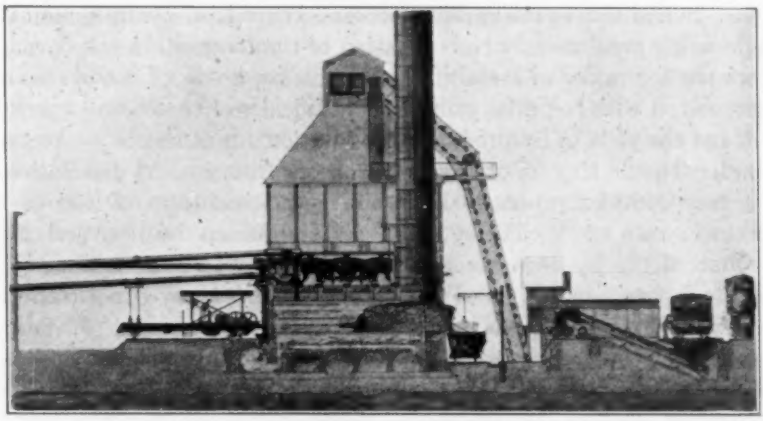

FIG. 5 SECTION OF SEMET-SOLVAY OVEN

partments with short horizontal travel for the gas. Every alternate flue is served by a gas burner, and all flues can be inspected by walking along the platforms at the ends of the oven. A series of dampers in the flues is arranged, which cause the gas to travel either the whole length of the flue system, or to pass directly to the next lower flue, in case the heating conditions of the oven demand it. These ovens may be built either with or without recuperators or regenerators.

38 The Koppers oven is of German development, and the first plant is now under construction in this country. It is a vertical flue oven of the Coppée type. Its essential features, as described in the American patents, are the special arrangements for the control of gas and air and their combustion in the oven flues. These consist

essentially of the arrangement of the ports, so that the gas and air travel spirally through the flues, thereby carrying the heat higher up in the oven and preventing local combustion at the point of entrance. Also a control of the effective area of each flue, so as to distribute the heat uniformly over the side of the oven chamber, and provision for examining all the flues through openings arranged for that purpose. The air, and sometimes the gas, are preheated in regenerators arranged underneath, one pair of regenerators for each oven.

39 In the by-product apparatus used in the various oven plants and in the general arrangement for handling the coal, coke, and other products, there are many variations, but these are rather to meet the conditions of the individual locations than inherent to any special oven system.

40 In addition to the various problems in mechanical and chemical engineering presented by the operation of the by-product coke oven, there are a number of metallurgical problems, some of which have been solved with material gain in the efficiency of the coking operation and the yield of by-products; the solution for others is yet to be found. The driving off of the hydrocarbons from coal by distillation is a very complex process. Each change in conditions of the temperature, rate of distillation, etc., gives different results, and on account of the hydrocarbons being so complex in composition, no definite figures can be placed on the operation. Many experiments, for example, have been made to determine the amount of heat absorbed in the coking process per unit of coal coked. Many processes have been devised for converting the major portion of the nitrogen in the coal into ammonia. These and other problems, however, are not much nearer solution than when the by-product process was first introduced into this country. The experience in the retort house of the gas works has shown that high heats and rapid coking increase the volume of the gas and tend to break down the heavier hydrocarbons, and the same is doubtless true in a measure in the retort oven, although the much greater bulk of the charge, the different relation between the volume of the gas produced in proportion to the heated surface of the retort, etc., modify these conditions.

41 The coking time of a charge in the oven depends upon the temperature of the heating flues, and the rate of transmission of the heat through the wall. Until recently "quartzite" brick have been used for these flue walls, in accordance with the European practice. Quartzite is the ordinary firebrick with sufficient quartz rock added to make the brick about neutral in its expansion and contraction,

and contains about 60 per cent silica. Recently, however, silica brick has been introduced somewhat generally, notwithstanding the additional complication of its considerable expansion under the temperatures of the oven chamber. Silica has the advantage of not being injured by the higher heats required by latest practice, and it is also a materially better conductor of heat than the quartzite. Magnesite is very attractive on account of its very high conductivity, but this material has not yet been successfully used.

42 The conductivity of firebrick increases with the temperature. There is no data available giving the exact relation of conductivity of either clay or silica brick at coking temperatures, but experience shows that a moderate increase in the thickness of the flue wall does not necessitate a materially higher temperature in the flue in order to maintain a given temperature in the coking chamber.

43 It has not been observed that the yield of coke from any given coal is affected by the speed of coking. When the coking operation is properly conducted, with entire exclusion of air, there is always deposition of hydrocarbons, and an increased yield of coke above the theoretical. This increase in yield is probably due to the pressures existing in the oven chamber, and the prolonged period of contact of the gases with the coal in process of coking. The retort oven always yields higher percentages of coke than can be obtained either in the crucible or in the gas retort, probably for the above reasons. The yields of by-products are not affected by temperature to anything like the same extent in the retort oven as in the gas retort where it is recognized that the higher temperatures produce larger volumes of gas higher in hydrogen and lower in hydrocarbons, together with lower yields of tar. As suggested above, these phenomena are doubtless due to the different relations between volume of retort and volume of charge.

44 The presence of water in the coal when charged increases the coking time, since, of course, the water must be driven off before the coking process begins, and therefore the penetration of the heat into the charge is delayed by that amount. The addition of water up to 10 or 12 per cent does not add seriously to the coking period, but the amount of heat absorbed is considerably increased, and there is also additional work thrown upon the condensing apparatus, in cooling the products of distillation.

45 The rate of distillation of the coal in the oven (known in practice as the coking time) varies with the quality of the coal and especially with the content of volatile matter; but this rate does

not vary directly with the percentage of volatile matter, probably because in the coals containing the most volatile matter distillation proceeds at a much more rapid rate during the early part of the process. This is illustrated by the accompanying table, showing the amount and composition of the gas produced from a low volatile and a high volatile coal during each hour of the coking process.

ANALYSES AND YIELD OF GAS FROM LOW VOLATILE COAL

Hour	Cu. ft. per hr.	CO_2	C_6H_6	C_2H_4	Total Ill.	O	CO	CH_4	H	N	B. t. u. per cu. ft.
1	536	0.1	0.5	6.0	6.5	0.8	4.6	31.6	42.1	14.3	643
2	425	0.1	0.7	3.6	4.3	0.8	4.3	32.8	51.6	6.1	638
3	475	0.1	1.1	3.8	4.9	0.7	4.9	33.2	46.8	9.4	641
4	357	0.1	0.9	3.3	4.2	1.1	4.6	33.5	49.6	6.9	637
5	411	0.1	0.8	3.7	4.5	0.8	4.6	33.1	50.8	6.1	644
6	401	No sa	mple	taken							
7	517	0.2	0.7	2.5	3.2	1.0	4.4	30.1	44.4	16.7	560
8	387	0.2	0.5	2.9	3.4	0.9	4.5	32.6	46.2	12.2	598
9	400										
10	320	0.0	0.4	1.6	2.0	0.9	4.1	29.1	47.4	16.5	
11	256										
12	189	0.1	0.5	1.2	1.7	0.6	4.6	29.5	53.6	13.9	
13	251										
14	256	0.1	0.2	0.6	0.8	0.9	4.4	17.0	69.2	17.6	
15	387	0.0	0.3	3.5	3.8	4.9	2.9	3.0	44.0	41.4	
16	425										
17	260										
18	37										
19	17										
20	0										
					Unpurified						
4		1.9	1.1	4.0	5.1	0.8	4.6	33.0	46.7	7.9	
6		2.0	1.2	3.3	4.5	0.9	4.4	30.0	44.7	10.0	
8		2.2	0.8	2.8	3.6	0.8	4.2	31.2	46.2	11.8	

Total cubic feet.....6307

46 The coke from the by-product or retort oven differs in some respects from that made in the beehive. On account of its being quenched outside of the oven it has lost the silvery glaze seen on the beehive coke. Formerly this was thought to be of some importance, as the glaze was supposed to help resist the action of carbonic acid on the coke in the blast furnace. Repeated experiments, however, have shown that the retort coke is rather more resistant to carbonic acid than beehive coke made from the same coal. Owing to the difference

in method of applying the heat the shape of the pieces of coke is different. This difference in structure is shown in Fig. 6. In the beehive oven the heat generated by the combustion of the gases above the coal works downward, developing a long finger-like structure. In the retort oven the heat is applied from both sides and works toward the middle, resulting in short blocky pieces somewhat less in length than half the width of the oven. Retort oven coke is somewhat denser than beehive coke from the same coal, the percentage of cells being slightly smaller.

ANALYSES AND YIELD OF GAS FROM HIGH VOLATILE COAL

Hour	Cu. ft. per hr.	CO_2	C_6H_6	C_2H_4	Total Ill.	O	CO	CH_4	H	N	B. t. u. per cu. ft.
1	829	0.9	0.9	3.2	4.1	0.5	5.8	41.5	41.4	5.8	693.4
2	562	0.9	1.0	2.6	3.6	0.4	5.1	40.4	43.8	5.8	681.5
3	582	0.9	1.0	2.1	3.1	0.7	4.9	37.6	47.2	5.6	654.2
4	582	1.1	1.1	2.1	3.2	0.4	5.0	36.2	48.6	5.5	648.5
5	582	0.8	1.0	1.7	2.7	1.0	4.6	33.3	49.5	8.1	588.6
6	452	1.1	0.9	1.6	2.5	1.1	4.6	31.4	49.8	9.5	583.8
7	490	2.2	0.9	1.3	2.2	1.6	4.4	31.0	47.6	11.0	586.2
8	449	0.9	1.0	1.5	2.5	0.5	4.8	31.5	54.2	5.6	603.0
9	432										
10	456	1.0	0.5	2.0	2.5	0.6	4.9	29.1	55.3	6.6	
11	474										
12	470	0.6	0.1	0.3	0.4	0.4	5.3	23.1	64.8	5.4	
13	494										
14	405	0.5	0.0	0.4	0.4	0.6	5.3	18.2	67.0	8.0	
15	460										
16	460	0.2		0.0	0.0	0.4	6.2	13.6	69.4	10.2	
17	386										
18	388										
19	148										
20	34										
21	48										
22	13										

Total cubic feet.....9194

47 There is still some difference of opinion among furnacemen as to the relative value of the two cokes in the blast furnace, owing to differences in individual experiences. Retort oven coke has received a great deal of criticism in this country because much coke has been made from coal which would be quite out of the question for use in the beehive oven. The reasons for using such coals were doubtless satisfactory to the management of the oven plants, but the coke produced has been often held up for comparison with Connellsville

beehive coke, which is perhaps the very best beehive product in the world. There are so many different grades of retort and beehive coke produced from the different coals, and under different conditions in the several plants in operation, and on this account a definite comparison of the two general types of coke is practically an impossibility. Some of the best furnace work in the country has been done with retort coke, which would seem to justify the statement that the best retort coke is as good as the best beehive coke in the blast furnace.

48 In the foundry cupola retort oven coke has an exceptional record, and in some localities it is without question the standard of foundry coke.

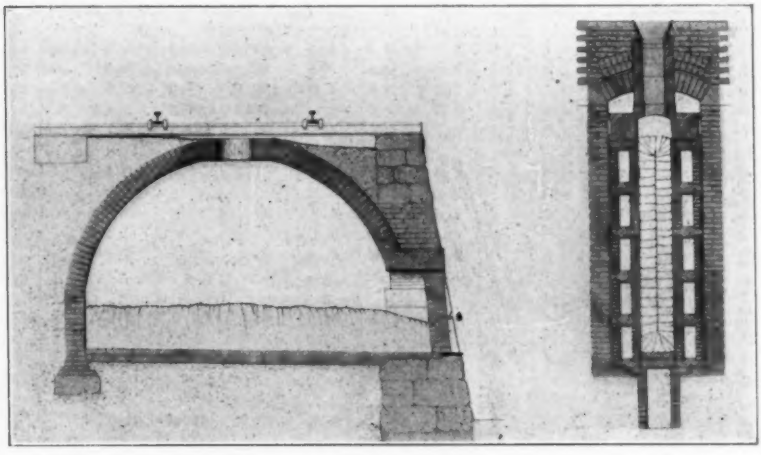

FIG. 6 STRUCTURE OF COKE IN BEEHIVE AND RETORT OVEN

49 In the beehive operation some of the fixed carbon is burned, while in the retort oven no combustion of the carbon can take place, and the yield is, therefore, up to or above the theoretical. On this account the retort coke is always somewhat purer chemically than beehive coke from the same coal. This gives the former a somewhat higher percentage of carbon, and lower percentage of ash, phosphorus, etc.

50 The by-products produced at plants operated in this country are tar, ammonia, gas and benzol. Cyanides are not being recovered at any of the American plants.

51 The tar is the standard coal tar of commerce, and does not differ materially from that produced by gas works. In Europe the

great briquetting industry is built up on the basis of tar from by-product ovens, since coal tar pitch is the only binder for briquettes which has been largely successful. Pitch constitutes from 60 to 70 per cent of the tar, the remainder being heavy oil, consisting of creosote oil, napthalene, anthracene, etc., and the light oils which are mainly impure benzols. These are separated by distillation, the pitch remaining as residue. As is well known, coal tar is the basis of a large number of important industries, especially in continental Europe but only a portion of the tar is available for these higher grade products. Anthracene is the raw material for alizarin, and napthalene is the basis of artificial indigo. Carbolic acid is formed from the creosote oils, and from the benzols are derived most of the long list of aniline colors, the manufacture of which has become such an important German industry.

52 The practical absence of these chemical industries in this country has been one of the causes of the relatively slow growth of the by-product oven here. While it may be some time before the manufacture of these refined products obtains an important foothold here, yet the briquetting industry, after many years of experimenting and failure, is at last becoming established commercially. Some half dozen plants located in different parts of the country have their product on the market on a commercial basis, and their growth should be rapid.

53 The low prices and high quality of coals that have been generally available, together with our high labor cost, have delayed the establishment of this industry here, but the increasing price of anthracite has encouraged the development of briquettes from the smaller and unmarketable sizes of anthracite from the coal yards and washeries in the East. In the Middle West the mining of some of the non-coking coals is accompanied with the production of a large amount of fine coal not available for general use. This and other relatively low priced coals form a considerable supply for briquetting. Farther west the lignites and semi-lignites offer a very promising field. Many of these coals break down badly upon exposure to the atmosphere into a fine powder which is practically useless. Briquetting prevents this disintegration, and a properly made briquette will stand a year's exposure to the elements without apparent injury, while the coal from which it is made would be reduced to a powder within a week or two. The engineers in charge of the Fuel Testing Station of the United States Government at St. Louis have made an interesting series of tests covering the briquetting of a large variety of coals, and

their results are most encouraging, especially on the classes of fuels last mentioned.

54 The process of briquetting is essentially a simple one, although the conditions necessary for success with each fuel must be definitely determined and maintained. The plants are not expensive or complicated, and now that works are operating commercially under widely different conditions and environments, a satisfactory growth of the industry should no longer be delayed.

55 The increased price of lumber and the destruction of our forests is bringing the preservation of lumber by creosoting prominently to the front, especially among the railroad companies for their ties, and the demand for creosoting oil is already increasing. New uses are being found for the benzol oils, as will be shown below.

56 Moreover, the application of tar to road surfaces is rapidly growing in favor. Especially since the introduction of the automobile it is found that no material produces a better road surface for the money expended than tar. This is sprinkled on the surface of the road and rubbed in with brushes, and if a penetration of an inch or so is effected, the surface of the road is impervious to water, and the presence of the tar produces an elastic condition of the surface which has a rather remarkable effect in increasing the wearing qualities of even indifferent road-making material. Tar can be quickly applied either to a new or an old surface, preferably the former. Dust is eliminated almost entirely, and by resprinkling every year or two, depending upon conditions of travel, material, etc., the road surface is kept in perfect condition, except, of course, for the replacement of material actually worn away.

57 By-product ovens have for some years been the leading producers of ammonia in this country. The total value of ammonia produced by gas works and by-product ovens together, in the year 1905, is given by the United States Geological Survey as $2 775 000. Figures are not available showing the output of the by-product ovens alone.

58 This ammonia is sold in the form of crude ammonia liquor, sulphate of ammonia, and aqua ammonia. The first named is an impure solution of the ammonia gas in water, containing some light tar oils, sulphur compounds, carbonates, etc., and contains from 15 to 25 per cent of ammonia. It is used in the ammonia soda industry, and also as a raw material for manufacturing higher grades of ammonia such as the nitrate and carbonate of ammonia, etc. Sulphate of ammonia, which is a grayish white crystal, containing about 25 per

cent of ammonia is largely used as a fertilizer, and also somewhat for the manufacture of anhydrous ammonia. In Europe the use of sulphate of ammonia as a fertilizer has been very greatly developed, partly by active educational methods, bringing home to the farmer the great gains from its use. It divides with nitrate of soda the responsibility for the great sugar-beet crops of continental Europe, and a great deal of study has been given to the intelligent application of this most available form of nitrogen to the varying crop conditions there found. In this country the development of the use of sulphate of ammonia as a fertilizer has only begun. While figures are not available showing the amounts of ammonia consumed in all the various uses, yet the following table will be of interest, showing a comparison of the ammonia productions of the several leading countries in the year 1906. This table is from a paper by Mr. C. G. Atwater in the last issue of the Mineral Industry. The figures represent all ammonia products figured as sulphate.

ESTIMATED AMOUNT OF THE WORLD'S PRODUCTION OF AMMONIA IN 1906

	Metric Tons
England	279 000
Germany	235 000
United States	68 000
France	49 100
Belgium and Holland	30 000
European other countries	55 000
Total	716 100

59 When we consider that the production of sulphate in this country was only 25 000 tons and that about 23 000 tons were imported during the year, the meager consumption of sulphate in this, the greatest of agricultural countries, is very striking. While, of course, the newer farming lands are still unimpoverished and do not require fertilizing, yet in all the older states crop yields have fallen off very greatly during the past generation, and yet the present use of artificial fertilizers is mainly confined to the Southern states on the cotton and tobacco fields. A consideration of our acreage of tilled land compared with that of Germany, for instance, will show the possibilities of the use of sulphate when our agricultural colleges and government agricultural stations have educated the farmers up to a full realization of the importance of this invaluable plant food. Aqua ammonia, which is essentially a purified solution of ammonia gas and water, containing about 25 per cent ammonia, is the refined

"ammonia" of commerce, although usually purchased in a very diluted form. During recent years its use has grown very rapidly for refrigerating purposes, both as aqua ammonia and as the source of anhydrous ammonia. The latter product is made essentially by driving the ammonia gas off from the water by heat, drying it and condensing it into a liquid by pressure.

60 The surplus gas from the by-product oven is the portion remaining after sufficient gas has been used for heating the ovens and the amount varies greatly with the coal used. In lean coals, low in volatile matter, there might perhaps be no surplus, while in rich gassy coals the amount may be from 4000 to 4500 feet per net ton of coal. As stated above, this gas is essentially similar to that made in gas works. Following is a typical analysis:

	Per cent.
Carbon dioxid	1.3
Benzene	1.2
Ethylene	4.2
Oyxgen	0.5
Carbon monoxid	5.1
Methane	35.5
Hydrogen	48.0
Nitrogen	4.2
B. t. u. per cubic foot, gross	679

61 If the gas is desired for sale for illuminating purposes and the richer portion is reserved for this purpose, as described above, the gas is richer in marsh gases and illuminants and contains less carbonic oxygen and hydrogen than the average made. The calorific value of the gas may vary from 550 to 700 B. t. u. per cubic foot. In this country its use for illuminating purposes has been developed much more than in Europe. There are now eleven plants supplying illuminating gas regularly for city consumption, and in 1905, 9 732 000 000 feet were sold, compared with 30 722 000 000 from coal gas works. In Europe the surplus gas has been largely consumed in gas engines. At one time there was some trouble on account of preignition of the gas, which was laid to the high percentage of hydrogen. This has been overcome, however, and the leading engineers no longer consider it an obstacle to its use for this purpose. It has been shown by Mr. Pennock in the Journal Society of Chemical Industry, June 15, 1905, that when coke oven gas is mixed with the proper amount of air for combustion, the mixture has not as high a percentage of hydrogen as producer gas, for example, which is largely used in engines without trouble from this cause.

62 Benzol is recovered from coke oven gas very largely in Europe, and is the raw material for the synthetic manufacture of the anilines and of carbolic acid, as well as a number of other chemical products. It forms the principal illuminant in coal gas, and its use is growing in this country as a convenient source of candle power, especially in small gas works. It is also used in the manufacture of varnishes.

63 Benzol has been used experimentally to a considerable extent both in Europe and in this country in explosion engines, both alone and mixed with alcohol. A series of carefully conducted tests in this country on stationary engines, motor boats and motor cars have brought out several points in its favor as a fuel for such engines. An equal volume has about 12 per cent more calorific value than ordinary gasolene. Owing perhaps to the fact that benzol is distilled within closer limits than gasolene, it has a somewhat higher thermal efficiency, and is not so liable to miss fire in the cylinder.

64 After this general review of the subject the question remains—What is to be the development of the by-product oven in this country? Compared with many industries its growth has been slow, but this, as has been pointed out, is largely due to the condition of the chemical industries in this country, which must of necessity keep pace, at least in a measure, with the sources of their raw materials. The capital required in the installation of the by-product oven is relatively large, and the results would have been serious if the rate of oven building had been greatly in excess of the demand for its by-products. In all industries depending upon the by-products of coke a promising future is apparent. The use of gas for illuminating purposes has become firmly established, and the rapid introduction of the gas engine affords a market for fuel gas. The various uses of ammonia in the arts have already been discussed. But we must look to agriculture as the principal consumer of any largely increased production of ammonia. Through the growing influence of Government and State Experimental Stations and agricultural colleges, science is being applied more and more to agriculture, and this cannot but lead to the general use of artificial fertilizers which naturally follows a higher standard of farm work. As a fertilizer base, sulphate of ammonia, with its nitrogen in the most available form, plays a most important part.

65 During the last few years the production of tar has exceeded the demand, so that large quantities have had to be burned as fuel at low prices, but the outlook for this by-product is more favorable than it has been. While it may be some time before the highly

specialized chemical industries for the production of anilines and dyes have reached any important growth, yet the prospects for the development of the cruder tar products are encouraging. The rapidly increasing price of lumber is forcing the necessity of creosoting, with the attendant consumption of creosoting oil, onto large lumber users like the railroad companies.

66 The practical start in the commercial manufacture of briquettes which has been described, promises an early development of that industry, and a very modest position as a producer of fuel would mean consumption of a large amount of pitch. If the number of by-product ovens and the output of tar therefrom were doubled, a production of less than 3 000 000 tons of briquettes per annum would consume all the pitch from this increase, without providing for any growth in the important roofing and paving industries, and without providing for any consumption of tar in the new tarred roads. This tonnage of briquettes, compared with the 60 000 000 tons of anthracite which will probably be produced this year, and the 340 000-000 tons of bituminous coal mined in 1906, suggests that briquetting, when once established, even as an "infant industry," may soon reach the condition which exists in continental Europe, namely, where its growth would depend only upon the available supply of pitch. Briquetting pitch must always be sold at a moderate price, unless the conditions of our fuel supply change materially. But, as in Europe, when once developed, briquetting will probably be the principal consumer of the pitch produced in this country.

67 The by-product oven belongs to the present day. The production of coke at the blast furnace plant, where the operation is assured by large storage of coal and where the labor is under better control than in less developed regions, is in line with today's manufacturing methods. The higher economy of its operation, its special adaptation to control by the modern scientific organization, the ability to draw coals from several fields, and the successful adaptation of labor saving appliances to its various operations, all point to its being the oven of the future.

THE STEAM PATH OF THE TURBINE

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1 Steam Equations

As steam is not a perfect gas, and in the form in which it is used in heat engines, usually not even homogeneous, but a mixture of vapor and condensed moisture, the equations of a perfect gas:

$$p\,V = \frac{r_0\,\theta}{M} \qquad [1]$$

and the adiabatic equation:

$$p\,V^a = \text{constant} \qquad [2]$$

where

p = absolute pressure, in kg. per m²;*
V = volume, in m³, per kg.;
θ = absolute temperature, in degrees centigrade;
M = molecular weight;
r_0 = a constant, = 848;
a = adiabatic constant, depending upon the number of atoms in the gas molecule;

can not directly be applied to steam.

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*In the following, the metric system of units will be used throughout, since the incongruous mixture of heterogeneous units, called the English system, requires so many reduction factors, that it can conveniently be used only in a narrow range of mechanical calculations, by memorizing reduction factors; but where the investigation extends over several branches of science, as mechanics, thermodynamics, and electrical engineering, the English system is so cumbersome, that it is far simpler to translate the premises into the metric system, carry out the work in the metric system, and translate the results back into the English system, if so desired.

2 Of the different sets of empirical equations, proposed for the thermodynamic behavior of steam, I find as most convenient for use and at least as closely in agreement with the experimental data, a set of equations similar to those of the perfect gas, [1] and [2]. That is:

For saturated steam:

$$p\,V^e = \text{constant} \qquad [3]$$

At adiabatic expansion:

$$p\,V^a = \text{constant} \qquad [4]$$

Where

$$\begin{aligned} e &= 1.064 \\ a &= 1.126 \end{aligned} \qquad [5]$$

3 In general, the relations between the mechanical constants of steam, as pressure, volume, energy, etc., can be expressed by simple and accurate equations, but more completed and less exact in their approximation are the relations between the mechanical and the thermal constants, and as far as possible it is preferable not to introduce the thermal constants into the equations.

4 Denoting then by the index O the steam constants at saturation, that is, with p_o, V_o, etc., the pressure per m², volume per kg., etc., of saturated steam, or steam which is neither superheated nor contains free moisture, the equations [3] and [4] can be written in the form:

SATURATION

$$p_o^{\frac{1}{e}}\,V_o = S \qquad [6]$$

where S is a constant:

$$S = 9900 \qquad [7]$$

or denoting

$$i = 1 - \frac{1}{e} = .06 \qquad [8]$$

$$p_o\,V_o = S\,p_o^{\,i}$$

or

$$V_o = \frac{S}{p_o^{\,1-i}} \qquad [9]$$

ADIABATIC

Denoting

$$c = 1 - \frac{1}{a} = .112 \qquad [10]$$

it is

$$p^{\frac{1}{a}} V = \frac{S}{p_o^{c-i}} \qquad [11]$$

or

$$V = \frac{S}{p^{1-c}\ p_o^{c-i}} \qquad [12]$$

where p_o is the saturation pressure corresponding to pressure p and volume V, that is, the pressure at which on the adiabatic curve $p\,V$ the steam reaches saturation.

ENERGY

5 The work done by the adiabatic expansion from pressure p_1 to pressure p_2, or the available energy of the steam of quality p_o, (that is, steam which adiabatically would reach saturation at pressure p_o), between pressures p_1 and p_2, is:

$$E = \int_{p_1}^{p_2} p\, d\, V$$

hence, substituting [12] and [9], gives

$$E = \frac{S}{a-1} p_o^{\,i} \left\{ \left(\frac{p_1}{p_o}\right)^c - \left(\frac{p_2}{p_o}\right)^c \right\} \qquad [13]$$

$$E = 78\,700\, p_o^{.06} \left\{ \left(\frac{p_1}{p_o}\right)^{.112} - \left(\frac{p_2}{p_o}\right)^{.112} \right\} \text{ kgm. per kg. steam}$$

And for saturated steam $p_1 = p_o$:

$$E^o = \frac{S}{a-1} p_o^{\,i} \left\{ 1 - \left(\frac{p_2}{p_o}\right)^c \right\} \qquad [14]$$

The *total energy of the steam* is, for $p_2 = O$, by [13]:

$$E_o = \frac{S}{a-1} \frac{p_1^{\,c}}{p_o^{\,c-i}} = 78\ 700 \frac{p_1^{\,c}}{p_o^{\,c-i}} \text{ kgm.} \qquad [15]$$

or by [12]:

$$E_o = \frac{p_1 V_1}{a-1} = 7.94\, p_1 V_1 \text{ kgm.} \qquad [16]$$

and for saturated steam, or at $p_1 = p_o$:

$$E_o^{\circ} = \frac{S}{a-1} p_o^{i} = \frac{p_o V_o}{a-1} \qquad [17]$$

This gives, at

$\frac{p}{10^4}$ =	0.1	0.2	0.6	1	2	4	6	8
E_o° =	119.0	124.0	138.5	136.5	142.5	148.5	152.5	155.0

$\frac{p}{10^4}$ =	10	12	14	16	20
E_o° =	157.0	158.8	160.5	162.0	164.0 x 10^3 kgm.

MOISTURE AND SUPERHEAT

6 When expanding from saturation pressure p_o, the volume of the moist steam at pressure p is, by [12]:

$$V = \frac{S}{p^{1-c}\, p_o^{c-i}}$$

if, however, the steam were saturated at pressure p, its volume would be, by [9]:

$$V_o = \frac{S}{p^{1-i}}$$

hence

$$\frac{V}{V_o} = \left(\frac{p}{p_o}\right)^{c-i}$$

is the ratio of the volume of the moist steam, to the volume of saturated steam, per kg. weight, at the same pressure; that is, neglecting the volume of the condensed moisture as small compared with the steam volume, $\frac{V}{V_o}$ is the steam contained in the mixture of steam and moisture, and

$$\gamma = 1 - \left(\frac{p}{p_o}\right)^{c-i} \qquad [18]$$

is the *moisture* of the steam.

7 Inversely, from the moisture γ and the pressure p, the saturation pressure p_o is determined by

$$p_o = \frac{p}{(1-\gamma)^{\frac{1}{c-i}}} \qquad [19]$$

8 Extending equation [18] to values of p greater than p_o, or into the region of superheat, the quantity γ becomes negative, and superheat appears as negative moisture, that is, is given by its moisture equivalent.

9 The *superheat* of steam may be represented by

$$\delta = -\gamma = \left(\frac{p}{p_o}\right)^{c-i} - 1 \qquad [20]$$

10 Representing the *specific heat of steam* by the empirical equation:

$$c_p = .46\left(\frac{p}{10^4}\right)^i \text{cal.} \qquad [21]$$

or, at

$$1 \text{ cal.} = 425 \text{ kgm.}$$

$$c_p = 195.5\left(\frac{p}{10^4}\right)^i \text{kgm.} \qquad [22]$$

and the *latent heat of evaporation* (at constant temperature), by the empirical equation:

$$\theta = 640 - 103\left(\frac{p}{10^4}\right)^{.193} \text{cal.}$$

$$= 272\ 000 - 43\ 800\left(\frac{p}{10^4}\right)^{.193} \text{kgm.} \qquad [23]$$

the *moisture equivalent of the superheat* of θ degrees centigrade then is

$$\delta = \left(\frac{p}{p_o}\right)^{c-i} - 1 = \frac{c_p}{\theta}\theta$$

$$= \frac{\theta}{1390\left(\frac{p}{10^4}\right)^{-.06} - 224\left(\frac{p}{10^4}\right)^{.193}} \qquad [24]$$

11 This gives, as the degrees centigrade superheat, equivalent to 1 per cent moisture, at a pressure, in kg. atmospheres:

$\frac{p}{10^4} =$	0.2	0.6	1	2	4	6	8	10	12	16
$\frac{\theta}{100\,\delta} =$	13.7	12.5	11.7	10.8	10.1	9.7	9.4	9.0	8.5	8.0 °C.

12 From [23] it follows, that the change of moisture (or change of superheat) per kgm. energy input into the steam (as heat produced by friction losses, etc.) at constant pressure, is

$$\Delta\gamma = \Delta\delta = \frac{1}{\theta} = \frac{1}{272\,000 - 43\,800\left(\frac{p}{10^4}\right)^{.193}} \qquad [25]$$

13 Hence, the change of saturation pressure p_o, to $p_o{}^1$, brought about by 1 kgm. heat input, is

$$\left(\frac{p}{p_o{}^1}\right)^{c-i} - \left(\frac{p}{p_o}\right)^{c-i} = \frac{1}{\theta}$$

$$p_o{}^1 = \frac{p}{\left\{\frac{1}{\theta} + \left(\frac{p}{p_o}\right)^{c-i}\right\}^{\frac{1}{c-i}}} \qquad [26]$$

2 The Steam Turbine

14 In the steam engine, the potential energy of steam is converted into reciprocating mechanical motion in the cylinders, and the reciprocating motion into rotary motion by crank and flywheel. In the steam turbine, the potential energy of the steam is converted into kinetic energy of the steam, that is, steam jet velocity, and this is converted into rotary mechanical motion. In the impulse turbine, the conversion of potential energy into kinetic energy of steam and of the kinetic energy of the steam into rotary motion, occur successively, the former in the stationary nozzles, the latter in the revolving wheels; in the reaction turbine, both conversions occur simultaneously, in the steam passages of the rotor, and in the combination turbine a part of the conversion of potential energy into kinetic energy of steam occurs in the stationary guide wheels, the other part in the rotating

wheels, while the conversion to rotary motion occurs in the rotating wheels. In either type of turbine, the potential energy is first converted into kinetic energy, that is, jet velocity.

15 The velocity produced by adiabatic expansion of a steam jet is given by

$$\frac{v^2}{2g} = E$$

as

$$v = \sqrt{2g\,E} \qquad [27]$$

hence by [15]

$$v = \sqrt{\frac{2g\,S}{a-1}}\; p_o^{\,i/2} \sqrt{\left(\frac{p_1}{p_o}\right)^c - \left(\frac{p_2}{p_o}\right)^c} \qquad [28]$$

$$= 1640 \left(\frac{p_o}{10^4}\right)^{.0} \sqrt{\left(\frac{p_1}{p_o}\right)^{.112} - \left(\frac{p_2}{p_o}\right)^{.112}}$$

16 The velocity due to expansion down to zero pressure, or into the vacuum, that is, the maximum possible velocity, therefore is, for $p_2 = O$:

$$v_o = \sqrt{\frac{2g\,S}{a-1}}\; \frac{p_1^{\,c/2}}{p_o^{\frac{c-i}{2}}} \qquad [29]$$

or, for $p_1 = p_o$, or saturated steam:

$$v_o^{\,n} = \frac{2g\,S}{a-1}\; p_o^{\,\frac{i}{2}} \qquad [30]$$

Dividing [28] by [29] gives

$$\frac{v}{v_o} = \sqrt{1 - \left(\frac{p}{p_1}\right)^c} \qquad [31]$$

hence, when expressed as fraction of the total velocity of expansion into the vacuum, the velocity depends only on the pressure ratio $\frac{p}{p_1}$, but does not depend upon the absolute pressure p and p_1, nor upon the quality of the steam p_o.

17 To illustrate the magnitude of these values:

Expanding saturated steam from 180 pounds per square inch to atmosphere, or 14.7 pounds:

$$p_1 = p_0 = 127\ 000 \quad p_2 = 10\ 350 \quad E = 39\ 000 \quad v = 875$$

From atmosphere to 28 inches vacuum, or

$$p_1 = p_0 = 10\ 350 \quad p_2 = 690 \quad E = 36\ 000 \quad v = 840$$

From 180 pounds per square inch to 28 inches vacuum:

$$p_1 = p_0 = 10\ 350 \quad p_2 = 690 \quad E = 75\ 000 \quad v = 1\ 210$$

From 180 pounds absolute to vacuum:

$$p_1 = p_0 = 127\ 000 \quad E_0 = 159\ 000 \quad v_0 = 1760$$

18 These velocities are of a far higher magnitude than those of high pressure water jets, and the problem of the steam turbine essentially has been to transfer economically such high jet velocities to the rotary wheel velocity.

19 An impulse wheel of velocity component parallel to the steam jet s, abstracts from the jet velocity v the velocity $2s$, so reducing it to $v - 2s$, and the theoretically most economical velocity of an impulse wheel is $s = \frac{v}{2}$, or half the jet velocity.

20 A reaction wheel of velocity s (parallel to the jet) abstracts the velocity s, so leaving the velocity $v - s$, and the most economical velocity of a reaction wheel is $s = v$, or the jet velocity.

21 A combination wheel—that is, impulse at the entrance, reaction at the exit—abstracts twice the wheel velocity, in two successive expansions and so gives the most economical wheel velocity $s = v^1$, where v^1 is the velocity due to half the pressure range, hence $s = \frac{v}{\sqrt{2}}$ if v = velocity due to total pressure range. That is:

The three types of turbines require theoretical wheel velocities respectively of $s = \frac{v}{2}, v, \frac{v}{\sqrt{2}}$, or in proportion of $1 + 2 \div 1.41$.

22 With an economical range of steam pressure, it is not possible to abstract economically the jet velocity by a single reaction or combination wheel, while with a single impulse wheel it seems possible only at limited outputs and by going close to the limits of mechanical strength of materials. (DeLaval.)

23 It is necessary therefore, in the steam turbine to convert the steam energy into mechanical rotation in a number of successive steps. In the reaction turbine and the combination turbine, these successive energy steps of necessity are pressure steps or expansions, while in the impulse turbine pressure steps or stages, and velocity steps are feasible.

24 As the velocity v varies with the square root of the energy E, a reduction of the jet velocity and so the wheel velocity to $\frac{1}{n}$ requires n^2 energy steps or pressure steps, or expansions.

25 In the impulse turbine, instead of converting the total jet velocity v in a single wheel, of velocity $s = \frac{v}{2}$, the same steam jet can be sent successively through a number of wheels, and with n wheels, each abstracting velocity $2s$, the theoretical wheel velocity is: $s = \frac{v}{2n}$. That is, to reduce the wheel velocity to $\frac{1}{n}$, at the same jet velocity, requires n wheels in tandem, or velocity steps.

26 While m pressure steps reduce the wheel velocity only to $\frac{1}{\sqrt{m}}$ of that of a single step, m velocity steps reduce the wheel velocity to $\frac{1}{m}$, and velocity steps are far more effective than pressure steps, in reducing the speed of rotation.

27 The use of velocity steps in the impulse turbine reduces the total number of revolving wheels and reduces the energy loss by wheel friction, windage, etc., and increases the simplicity and the reliability of the turbine, but increases the energy loss by steam friction and degeneration, due to the higher jet velocity, and the proper number of pressure steps, and of velocity steps in each pressure step, as determined by considerations of efficiency, therefore, is a problem of design, and as such is outside of the scope of this paper. In general, in slow speed turbines a larger number of velocity steps per pressure step or stage is economical, than in high speed turbines.

3 CONVERSION OF POTENTIAL ENERGY TO KINETIC ENERGY OF THE STEAM

28 If V = volume of the expanding steam, per kg. weight, and v velocity, the section of the steam jet, which discharges one kg. of

steam per second, that is, the nozzle section per kg. per second of steam, is

$$q = \frac{V}{v}$$

and, substituting herein [12] and [28], gives

$$q = \frac{(a-1)\,S}{2g} \cdot \frac{1}{p_o^{\frac{c-i}{2}}\, p^{1-c} \sqrt{p_1^c - p^c}}$$

$$= \frac{7.974}{p_o^{\frac{c-i}{2}}\, p^{1-c} \sqrt{p_1^c - p^c}} \qquad [32]$$

29 The minimum section, q^1 is found by $\frac{dq}{dp} = O$, at the pressure:

$$\frac{p^1}{p_1} = \left(\frac{2-2c}{2-c}\right)^{\frac{1}{c}} = \left(\frac{2}{a+1}\right)^{\frac{1}{c}} = .579 \qquad [33]$$

and is, by substituting [33] in [32]:

$$q^1 = \frac{(a+1)\,S}{2g} \cdot \frac{\left(\frac{a+1}{2}\right)^{\frac{1}{a-1}}}{p_o^{\frac{c-i}{2}}\, p_1^{1-\frac{c}{2}}}$$

$$= \frac{37.1}{p_o^{.026}\, p_1^{.944}}$$

and this minimum section q^1 is called the *throat* of the nozzle or steam passage.

30 Expressed by its ratio to the throat section, or minimum section, the section of the steam jet is

$$\frac{q}{q^1} = \frac{\sqrt{\frac{a-1}{a+1}}\left(\frac{2}{a+1}\right)^{\frac{1}{a-1}}}{\left(\frac{p}{p_1}\right)^{1-c} \sqrt{1-\left(\frac{p}{p_1}\right)^c}}$$

$$= \frac{.733}{\left(\frac{p}{p_1}\right)^{.888} \sqrt{1-\left(\frac{p}{p_1}\right)^{.112}}} \qquad [35]$$

31 That is, while the minimum section, or throat, depends upon the pressure p, the pressure p_1, at which the expansion starts, and the quality of the steam, as characterized by the saturation pressure p_o, the relative section of the expanding steam jet depends only on the pressure ratio $\frac{p}{p_1}$.

32 By equation [31] it is

$$\frac{p}{p_1} = \left\{ 1 - \left(\frac{v}{v_o} \right)^2 \right\}^{\frac{1}{c}} \qquad [36]$$

and, substituting [31] and [36] into [35], expresses the relative nozzle section by the velocity ratio $\frac{v}{v_o}$; that is, the ratio of the kinetic energy to the total energy of the steam:

$$\frac{q}{q^1} = \frac{\sqrt{\frac{a-1}{a+1}} \left(\frac{2}{a+1} \right)^{\frac{1}{a-1}}}{\frac{v}{v_o} \left\{ 1 - \left(\frac{v}{v_o} \right)^2 \right\}^{\frac{1}{a-1}}} \qquad [37]$$

$$= \frac{.733}{\frac{v}{v_o} \left\{ 1 - \left(\frac{v}{v_o} \right)^2 \right\}^{7.94}}$$

33 Substituting [33] into [31], gives the throat velocity:

$$\frac{v^1}{v_o} = \sqrt{\frac{a-1}{a+1}}$$

$$= \sqrt{.05927} = .2434 \qquad [38]$$

that is, at the throat or minimum steam section, 5.927 per cent of the total energy of the steam is converted, giving a velocity equal to 24.34 per cent of the velocity of expansion into a vacuum.

34 For illustration are given, the steam section, with the throat or minimum section as unit ordinate, and with the pressure ratio $\frac{p}{p_1}$ as asbscissae in Fig. 1, with the velocity ratio $\left(\frac{v}{v_o} \right)^2$ as abscissae in Fig. 2.

35 For pressure ratios $\frac{p_2}{p_1} > .579$, the expansion nozzle contracts from the intake to the outlet or mouth, while for pressure ratios $\frac{p_2}{p_1} < .579$, the expansion nozzles first contract, to a minimum at the throat, at pressure $p^1 = .579\ p_1$, and then expands again toward the mouth.

36 The shape of the nozzle depends upon the distribution of pressure or velocity, and the rate of energy conversion. Fig. 2, for instance, would correspond to what would be the shape corresponding to constant rate of energy conversion. A slower rate of energy conversion leads to a longer nozzle, or steam passage, and so greater friction losses; a more rapid rate of conversion to irregularity of the velocity, and a greater divergency of the outflowing steam jet, so that efficiency considerations determine the design of the nozzle or steam passage regarding its energy distribution. The efficiency of conversion of a well designed nozzle is very high, giving a mean velocity of the steam jet as high as 97 to 98 per cent and more of the theoretical jet velocity.

4 CONVERSION OF STEAM JET VELOCITY INTO MECHANICAL ROTATION

37 In the steam passages of the revolving wheels, the kinetic energy of the steam is transferred to the rotor, and also, in reaction and combination turbines, potential energy, that is, pressure, is converted into kinetic energy of steam, that is, velocity. In the impulse turbine, no conversion of steam pressure to velocity occurs in the rotor, and so no pressure differences exist between the two sides of the rotating wheels.

38 Usually, the steam jet enters the rotating wheel on one side, as nearly tangential as possible, and leaves it at the other side.

39 Let then

s = velocity of the rotating wheel, at the pitch center of its steam passages, in meter seconds.

v = velocity of the steam jet.

the velocity v can be resolved into the three components:

$$\left.\begin{aligned} v' &= \text{in the direction tangential with the rotor, or parallel to its motion } s \\ v'' &= \text{in axial direction parallel to the shaft of the rotor} \\ v''' &= \text{in radial direction.} \end{aligned}\right\} [37]$$

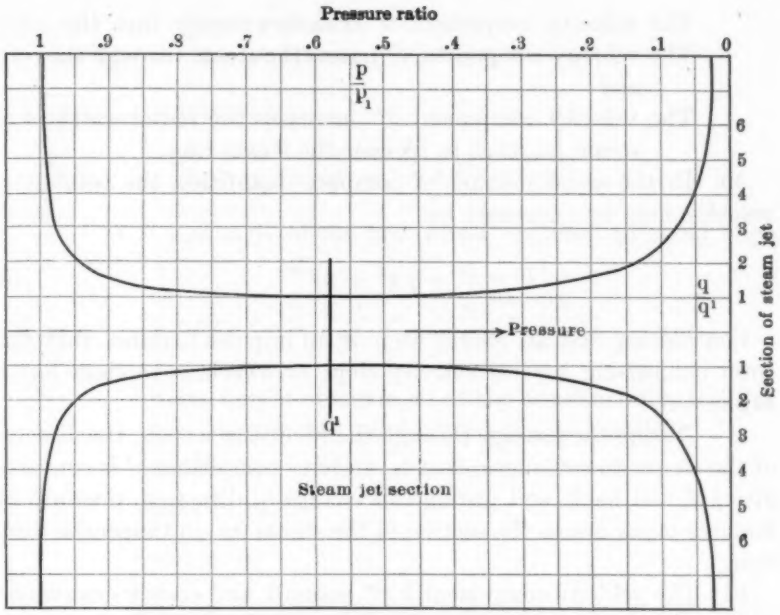
Pressure ratio
1 .9 .8 .7 .6 .5 .4 .3 .2 .1 0
p/p1
q/q1
Pressure
Section of steam jet
q1
Steam jet section
1 2 3 4 5 6
6 5 4 3 2 1

FIG. 1

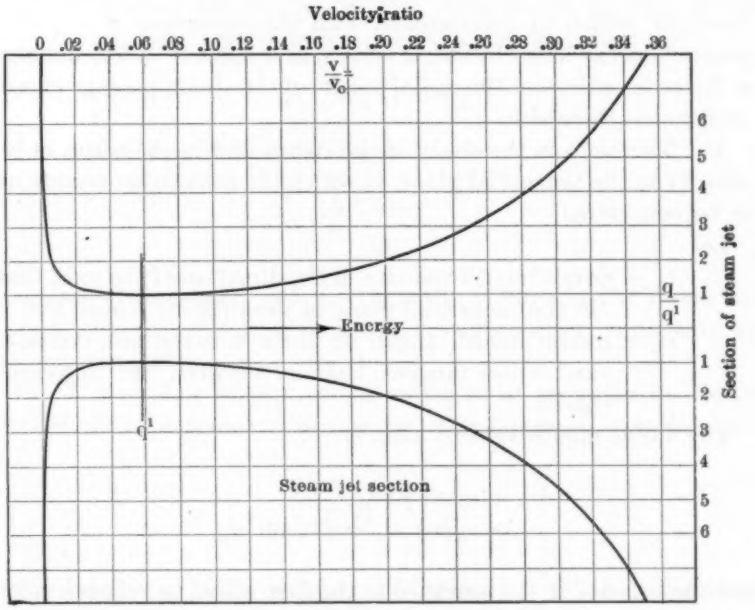
Velocity ratio
0 .02 .04 .06 .08 .10 .12 .14 .16 .18 .20 .22 .24 .26 .28 .30 .32 .34 .36
v/v0
q/q1
Energy
Section of steam jet
q1
Steam jet section
1 2 3 4 5 6
6 5 4 3 2 1

FIG. 2

The velocity component v' transfers energy into the rotor.
The velocity component v'' passes the steam through the rotor, and
The velocity component v''' increases the radial width of the steam jet, that is, spreads the steam ring.

40 In the usual manner of complex quantities, the total steam velocity may be expressed by

$$V = v' + j\,v'' + kv''' \qquad [38]$$

Considering first an energy step of an impulse turbine, that is, a rotor comprising several velocity steps or wheels in tandem but no expansion.

41 During the passage through the revolving wheels, the direction of the steam flow changes; that is, velocity component v' is converted into $j\,v''$ and back, and during this change of direction, pressure differences occur across the section of the steam jet, in tangential direction.

42 The velocity component $k\,v'''$ is small, and since its conversion to v', by a contraction of the radial height of the steam passage, would result in pressure differences across the steam passage in radial direction, which by interference with the conversion $v' \div j\,v''$ may produce energy losses by steam eddies, as a rule $k\,v'''$ is left unchanged as far as feasible, and the radial height of the steam passage chosen in conformity therewith.

43 Therefore in the study of the steam flow in the rotor, only the velocity in the tangential plane, in which the conversion occurs, needs to be considered.

Let

v_o = nozzle mouth velocity in the direction of the axis, that is, in the tangential plane of the rotating wheel, and
ω_o = nozzle mouth angle, or angle between the nozzle axis and wheel tangent, that is, between the velocities v_o and s.

The nozzle mouth velocity then is

$$\begin{aligned} V_o &= v_o' + j\ v_o'' \\ &= v_o \cos.\ \omega_o = j\,v_o \sin.\ \omega_o \end{aligned}$$

and the velocity at the entrance to the first wheel, or relative velocity between the steam jet and the wheel, is

$$V_1 = v_1' + j\, v_1''$$
$$= (v_0 \cos.\, \omega_0 - s) + j\, v_0 \sin.\, \omega_0$$

hence, its absolute value:

$$v_1 = \sqrt{(v_0 \cos.\, \omega_0 - s)^2 + v_0^2 \sin^2.\, \omega_0}$$

and the entrance angle of the first wheel, required to avoid impact losses, is

$$\tan.\, \omega_1 = \frac{v''_1}{v_1'} = \frac{v_0 \sin.\, \omega_0}{v_0 \cos.\, \omega_0 - s}$$

If

h_0 = radial height of steam jet at the nozzle mouth, the steam section per unit pitch at the nozzle mouth is

$q_0 = h_0 \sin.\, \omega_0$

and at the wheel entrance

$$q_1 = h_0 \sin.\, \omega_1$$

44 During the passage through the wheel, the steam velocity v_1 decreases by a friction coefficient f_1, which represents the energy losses by external and internal friction of the steam, and the absolute value of the relative outflow velocity from the first wheel is:

$$v_2 = v_1 (1 - f_1)$$

45 The energy loss in the wheel

$$\frac{v_1^2 - v_2^2}{2g}$$

is converted into heat, and increases the volume of the steam from V_1 to V_2, by evaporation of moisture, or superheat, in conformity with the equation [25].

46 The outflow section of the steam must be larger in the proportion of the decreased velocity and the increased volume, hence is

$$q_2 = q_1 \frac{V_2}{V_1} \frac{v_1}{v_2}$$

47 Due to the radial component of velocity, $k\, v'''$, the radial height of the steam jet had increased during its passage through the wheel,

to h_2, and with a pitch section q_2 and radial height h_2, the width of the outflow passage is

$$\text{sin. } \omega_2 = \frac{q_2}{h_2}$$

48 In a similar manner, the respective section of the steam flow throughout the passage through the wheel, and therefore the thickness and shape of the blades, are determined.

49 The width of the outflow passage determines the theoretical exit angle of the first wheel, and gives the vector representation of the outflow velocity:

$$V_2 = v_2 \text{ cos. } \omega_2 - j\, v_2 \text{ sin. } \omega_2$$

50 The outflow velocity in space then is

$$\begin{aligned} V_3 &= V_2 - s \\ &= (v_2 \text{ cos. } \omega_2 - s) - j\, v_2 \text{ sin. } \omega_2 \end{aligned}$$

hence

$$v_3 = \sqrt{(v_2 \text{ cos. } \omega_2 - s)^2 + v_2^2 \text{ sin.}^2 \omega_2}$$

and its angle:

$$\text{tan. } \omega_3 = \frac{v_2 \text{ sin. } \omega_2}{v_2 \text{ cos. } \omega_2 - s}$$

51 As this velocity v_3 is in backward direction, the second wheel of a pressure step, comprising several velocity steps, must either revolve in opposite direction, or a stationary intermediate must be interposed, which again turns the steam into the forward direction. The latter usually is the case.

52 v_3 then is the entrance velocity, and ω_3 the entrance angle, and by the same consideration as above, herefrom follows the exit velocity and the exit angle of the intermediate, as

$$\text{sin. } \omega_4 = \frac{q_4}{h_4}$$

$$v_4 = v_3\ (1 - f_3)$$

$$v_4 = v_4 \text{ cos. } \omega_4 + j\, v_4 \text{ sin. } \omega_4$$

and the relative entrance velocity into the revolving wheel, and the entrance angle:

$$V_5 = (v_4 \cos. \omega_4 - s) + j\, v_4 \sin. \omega_4$$

$$\tan. \omega_5 = \frac{v_4 \sin. \omega_4}{v_4 \cos. \omega_4 - s}$$

etc., until at the outlet of the last wheel, the remaining velocity v_n is rejected, that is, converted into heat.

53 As illustration is shown, in Fig. 3, the steam path from nozzle to exhaust, through three rotating wheels and two intermediates, for the constants:

$$v_o = 850\ ms \qquad s = 120\ ms$$

54 From the velocities follow the amount of kinetic energy, converted into mechanical rotation or lost:

$$\frac{v_o^2}{2g} = \text{kinetic energy of steam jet at nozzle mouth.}$$

$$P = \left[\frac{v_o^2 - v_1^2}{2g} + \frac{v_3^2 - v_3^2}{2g}\right] + \left[\frac{v_4^2 - v_5^2}{2g} + \frac{v_6^2 - v_7^2}{2g}\right]$$

$$+ \ . \ . \ . = \text{mechanical output at rotor}$$

$$L = \frac{v_1^2 - v_2^2}{2g} + \frac{v_3^2 - v_4^2}{2g} + \frac{v_5^2 - v_6^2}{2g}$$

$$+ \ . \ . \ . = \text{losses in wheels and intermediates}$$

$$R = \frac{v_n^2}{2g} = \text{rejected energy}$$

and $\dfrac{P}{P + L + R}$ is the efficiency of conversion of the kinetic energy into mechanical motion, which corresponds to the *indicated efficiency* of the steam engine.

55 The "lost energy" $L + R$ is converted into heat, and so not entirely lost, but a part of it recovered in the next following pressure steps.

56 If the expansion takes place in the steam passages, as in the stationary intermediates of the impulse turbine, and in the stationary guide wheels and revolving wheels of the combination turbine, the preceding calculations of the steam path remain the same, except that between the entrance and the exit values of the steam passage the effects of expansion are interposed.

57 For instance, in the first wheel of the preceding discussion, if during the passage of the steam through this wheel the pressure falls,

from p_1 to p_2, superimposed upon the change of velocity in the wheel, by friction, is the increase of velocity due to expansion in the steam passage as a nozzle.

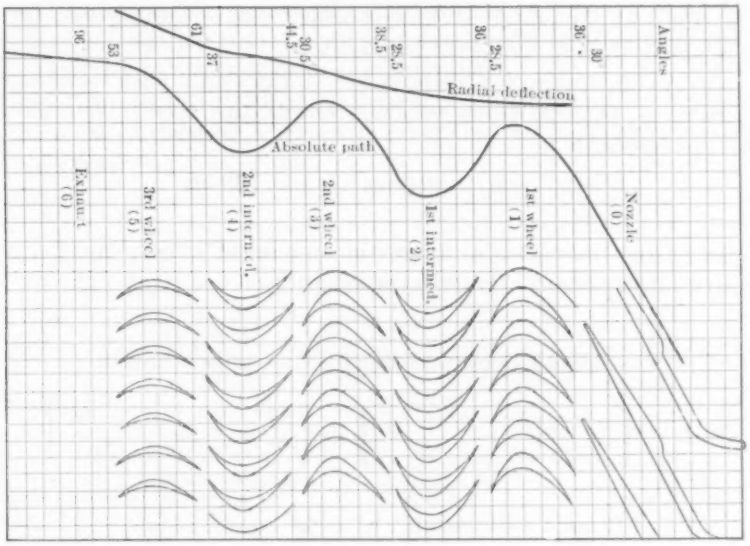

FIG. 3

58 Thus, the entrance velocity v_1, at pressure p_1 and steam quality p_o (that is, saturation pressure p_o), corresponds to an expansion from a pressure p_s. That is, expanding from pressure p_s to p_1, the steam would acquire the velocity v_1. The pressure p_s is given by equation [28]:

$$v_1 = \sqrt{\frac{2g\ S}{a-1}}\ p_{o2}^{\frac{i}{c}}\ \sqrt{\left(\frac{p_s}{p_o}\right)^c - \left(\frac{p_1}{p_o}\right)^c}$$

as

$$p_s = p_o\left\{\frac{a-1}{2g\ S}\frac{v_1^2}{p_o^{\frac{i}{c}}} + \left(\frac{p_1}{p_o}\right)^c\right\}^{\frac{1}{c}}$$

and the theoretical exhaust velocity v_2 then follows from p_s and p_2, as

$$v_2^1 = \sqrt{\frac{2g\ S}{a-1}}\ p_o^{\frac{i}{c}2}\ \sqrt{\left(\frac{p_s}{p_o}\right)^c - \left(\frac{p_2}{p_o}\right)^c}$$

which gives

$$\frac{v_2^1}{v_1} = \sqrt{\frac{p_s^c - p_2^c}{p_s^c - p_1^c}}$$

and the velocity v_2^1 now is reduced by the friction coefficient f_1 referred to a mean velocity:

$$v_2 = v_2^1 - \frac{v_1 + v_2^1}{2} f_1$$

while the steam volume is increased from V_1 to V_2^1 by the expansion, in accordance with equation [12]:

$$\frac{V_2^1}{V_1} = \left(\frac{p_1}{p_2}\right)^{1-c}$$

and still further, to V_2, by the heat produced by the energy losses.

59 From the volume and the velocity then follows the exit section q_2 of the steam, and so the product:

$$h_2 \sin. \omega_2 = q_2$$

60 In this case, where expansion occurs in the steam passages, the maintenance of the radial velocity kv''' is of no object, and the relations between h and ω are chosen from other considerations.

61 The radial height may be assumed as constant: $h_2 = h_0$ then the successive angles ω_0. ω_2, ω_4 increase.

62 Or it may be assumed:

$$\omega_2 = \omega_0$$

that is, the shape of the steam passage may be assumed the same, but merely the height increased with increasing expansion, or in successive turbine sections, first the one and then the other quantity may be assumed as constant, in accordance with the requirements of mechanical design.

63 While thus the calculations of the steam path of the impulse turbine with pressure and velocity steps, and of the combination turbine with expansion in stationary guide wheels and revolving reaction wheels, is essentially the same, the shape of the blades and of the steam path differs considerably in the two types, due to their specific characteristics.

64 In the multiple wheel impulse turbine, in successive wheels the entrance and exit angles gradually increase, from the nozzle toward the exhaust. That is, tan. ω increases, due to the decrease of v' by the abstraction of the speed s at every transition between moving and stationary elements: the tangential velocity v' of the steam decreases, from a maximum, and nearly equal to the total steam velocity, at the nozzle mouth, to practically zero at the exhaust from the last wheel. The axial velocity $j v''$ however, decreases only in proportion to the increasing height of the steam passages, and so remains more nearly unaltered, as it is the velocity which passes the steam through the passages in wheels and intermediates. The ratio of these velocities, or the tangent of the entrance and exit angles, increases rapidly, as seen in Fig. 3.

65 In the combination turbine, with expansions in every wheel, as a rule v_0 and s do not greatly differ, and all the entrance angles are large, approximating 90 degrees, while the exit angles are small, the former corresponding to the low relative steam velocity at the entrance, the latter to the higher relative velocity at the exit after expansion.

66 It is obvious that many considerations of design, regarding mechanical construction, efficiency as resulting from a compromise between the different losses, etc., more or less modify the above theoretical reasoning, but cannot be discussed in a short paper. A number of other conditions also require consideration, for instance, during the passage of the steam through a number of successive wheels, starting as a jet in a tangential plane, and curving in the steam passages of radial walls, from the lateral deflection results in an increase of the radial distance of the steam jet during its passage, that is, a "radial deflection of the steam jet," as shown in Fig. 3, which then requires an increase of the pitch diameter of the successive steam passages of successive wheels of the same pressure step.

5 THE LOSSES AND THE ENERGY FLOW

67 Investigation of the steam path of the turbine, together with a knowledge of frictional constants and their variation, allows a study of the components of the output and the distribution and magnitude of the losses, and therefrom a determination of the energy flow in the turbine. Illustrating this on a multi-stage multiple wheel impulse turbine:

68 Mechanical energy of rotation is produced from kinetic energy of steam, in the steam passages of the rotating wheels, and mechanical

energy is consumed by conversion into heat, by friction and windage at the surfaces of the revolving wheels and in the bearings.

69 Kinetic energy of steam is produced from the potential energy of steam, in the expansion nozzles. Kinetic energy of steam is consumed by steam friction and eddies in the nozzles, wheels and intermediates, and is consumed by rejection in the exhaust of each pressure step.

70 Potential energy of steam is produced from the heat energy derived from the conversion of the energy losses into heat, in the form of an increase of the quality of the steam, that is, decrease of the saturation pressure p_o and of the moisture, and potential energy is consumed by the leakage between the stages.

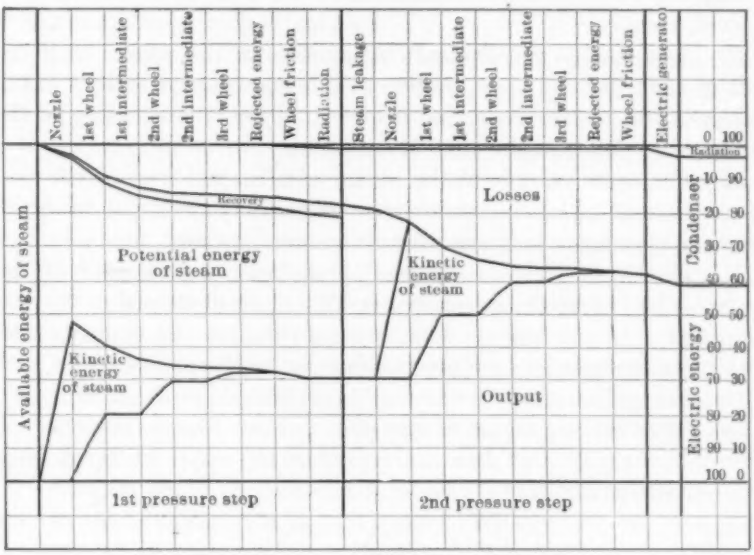

FIG. 4

71 Heat energy is produced by all the above energy losses, and is consumed by radiation.

72 The energy consumed by mechanical and steam friction is not entirely lost, except in the last and lowest pressure step, but a part of it is recovered in the lower pressure steps or expansions, and the potential energy of the steam leakage from stage to stage is partly recovered in the lower stages, in the same way.

73 The different forms of energy losses are not equivalent, since the losses of kinetic and potential energy multiply with the efficiency

of conversion from kinetic potential energy respectively to mechanical energy, in their effect on the output. That is, if γ_o = efficiency of conversion of the kinetic energy of the steam into mechanical rotation, γ = efficiency of conversion of the potential energy, or total available energy, of the steam into mechanical energy, a loss of L kgm., of mechanical energy, lowers the output by L kgm., but a loss of L kgm. kinetic steam energy lowers the output only by $\gamma_o L$ kgm. and a loss of L kgm. of potential energy only by γL kgm., without counting the energy recovered in the lower expansions.

74 Starting then with the total available potential steam energy, as it enters from the steam supply, as 100 per cent, as illustrated in Fig. 4, is shown the log of the energy conversion in a steam turbine having two pressure steps or stages, and three velocity steps or wheels in each stage.

75 As seen, the mechanical output rises in the wheels and decreases again by the wheel friction in the first stage, increases in the wheels of the second stage, and decreases in the wheel friction of the second stage, and in the generator losses.

76 The kinetic energy of the steam rises in the first nozzle, decreases to nothing by conversion to mechanical output and to heat, and then rises again in the nozzles of the second stage.

77 The losses steadily increase throughout, but a part of the losses of the first stage, as marked in Fig. 4, are recovered in the second stage. Of the leakage loss between the first and second stage, nothing is recovered in the present case, since the recovery of a part of the leakage loss would occur only in a third stage.

78 Attached log of an energy distribution, Fig. 4, obviously is merely illustrative, but does not represent the exact energy flow in any particular turbine.

DISCUSSION

POWER SERVICE IN THE FOUNDRY

By A. D. Williams, Jr., Published in October Proceedings

Mr. Ronceray[1] I desire to say a few words in favor of water pressure. I have had experience with it, especially in connection with molding machines, while I have also had experience with compressed air in the pneumatic tool business.

2 I do not agree that it is more difficult to keep a water line tight than it is to keep a compressed air line tight. Indeed, I think the difficulty that might happen is that in many cases the air line has to be made very big in size as compared with what is really necessary in a well designed system of hydraulic pressure. We very seldom use a pipe line larger than half an inch in diameter, even for large molding machines, and under these conditions we have never found any trouble in keeping a water line tight.

3 The practice that we have followed in Europe in molding machines is to use copper pipes, which are easily bent to suit conditions, instead of iron pipes with all their numerous joints and elbows. The joints are therefore much less in number than in an iron pipe air line. I have never found any difficulty in keeping a half-inch copper pipe line tight.

4 Another point: there is no reason why a valve, in hydraulic service, cannot be designed so as to be tight. We have a valve, designed for water, which gives entire satisfaction. It is impossible to keep a metallic seated valve tight. The only way to keep a valve tight is to use leather packing; the trouble in hydraulic valves having leather packings is generally that the leather is scratched in passing the ports; the valve we have designed is similar to a poppet valve with a leather seat, and in our practice, when we use good leather packing we never have a leak.

5 It is very easy to make this experiment. If you have a reservoir in which your compressed air is stored and leave it charged at night,

[1] With the Universal System of Machine Molding, Philadelphia, Pa.

the following morning you are pretty sure to find the pressure down; while it is quite common, with a hydraulic accumulator left at a certain level at night, to find it at the same level the following morning.

MR. J. E. JOHNSON, JR. The writer wishes to confirm what was said about the ease of keeping air lines in order. At the plant of the Princess Furnace Company, Glen Wilton, Virginia, there is an air line five inches in diameter 8000 feet long. No trouble whatever has been experienced with it and it has been in operation for over a year. Long sleeve couplings and expansion joints were put in at intervals to take care of changes in temperature.

2 The old theory that air is harder to hold than steam is a technical untruth that has been circulated long enough. If steam starts to leak, it will eat almost like an acid, and can never be made tight. Whereas with air it is only necessary to tighten the joint that is leaking. The constant working from expansion and contraction caused by variation in temperature with steam makes it much more difficult to keep tight. This is aside from any consideration of condensation losses.

3 The statement in Mr. Williams' paper that it has been found profitable to put in an electric transmission in big excavation work the writer does not believe will be borne out by practical experience. Running through the calculation in this very case shows that the cost of electrical transmission, outside of the engine, would be about $12 500, while the cost of the pipe line was only $1500. Counted roughly, the cost of the compressor would be about the same as that of the power engine, for the reason that the compressor required in the steam cylinder about 160 horse power; and to deliver the same amount of air at the same point with the electrical apparatus would require 250 horse power, giving a net efficiency of 87 per cent, against only about 56 per cent. Furthermore, the initial cost was three or four times as much for electricity.

4 The proposition to transmit by electricity and then transform the energy into compressed air will not work on a commercial scale for distances short of five miles.

MR. S. D. SLEETH[1] In the Westinghouse Air Brake Company's foundries both air and water are used; water on certain machines at a high

[1] Non-member, superintendent of foundries, Westinghouse Air Brake Company, Wilmerding, Pa.

pressure (1300 pounds), which permits the use of a very small cylinder. If air were used on these machines it would require a much larger cylinder. Leaks can be discovered in a water line where they would not be noticed in an air line. It is much easier to keep an air line tight than to keep a water line tight, for there is not the pressure and the expansion and contraction in cold weather.

2 The principal reason for using water in these foundries is on account of its small volume and positive action.

MR. H. M. LANE The locomotive crane has not been given sufficient attention in the foundry. There have been a great many attempts to get some system for taking the flasks in and out of a foundry to and from the flask storage. The writer is of the opinion that all light flasks should be stored under shelter. Of course large flasks and heavy rigging can frequently be stored in the open to advantage.

2 In many cases the traveling crane runway is extended through the end of the foundry so as to cover a portion of the yard. This is impracticable in this Northern climate, where serious effects upon the health of the craneman may result from running out over the yard in zero weather with insufficient protection from the cold. In case of resulting illness the substitution of a new man necessarily retards the work, which is expensive.

3 Then, too, whenever the crane runs out through the end of the foundry, practically the entire end of the building has to be removed, and particularly the upper part where there is the hottest air. As a consequence, the heat all goes out and the zero weather comes in. The next effect is that the men all leave their work and congregate around the salamanders, so that the expense of running the crane through the end of the foundry may be very great. In fact, it may virtually result in the stopping of practically all work for several hours on days when the end of the building is open very much.

4 To overcome this difficulty, several foundries have run a track down through the middle of the building. The locomotive crane then enters the building through a comparatively low door, without letting all of the hot air out.

5 This crane can bring carloads of flasks and distribute them along the floor wherever they are wanted. The long boom of the locomotive crane will frequently be convenient as an auxiliary crane on special work. In fact, it is serviceable both indoors and out, enabling the foundry management to accomplish vastly more than could be done without its service.

6 When a locomotive crane goes out of doors flasks can be piled just as far as the boom will reach. When the yard is full space can be rented somewhere near. When the locomotive crane service is installed there is no expense for overhead runways, as in the case of traveling cranes, the only outlay being for railroad track, which may also be used for shifting cars.

7 In a mining enterprise, in which the writer engaged some years ago, it was necessary to deal with various kinds and types of pipe lines, 2000 or more feet long. Among other difficulties, there were those due to expansion and contraction, insulation, and hidden joints. In one mine there were about 30 or 40 miles of air pipe lines running from central stations. Air was carried over mountains to another mine, and on that line, which was several miles long, air was sometimes left on the line over a holiday and at the end of 48 hours the pressure had not fallen over ten pounds.

8 No difficulty was found in keeping those long lines practically tight with compressed air, with a variation of temperature of from 50 degrees below zero in winter to 110 degrees in summer. Therefore there should be no difficulty in keeping the air mains tight in a foundry.

9 What Mr. Ronceray says about the hydraulic lines is true. In the course of investigations a few years ago, of installations of hydraulic power in a large number of steel works, the writer was surprised at the tightness of their lines, due perhaps to the small diameter of the pipes and the care with which the joints were made.

THE FOUNDRY DEPARTMENT AND THE DEPARTMENT OF ENGINEERING DESIGN

By W. A. Bole, Published in September Proceedings

Mr. H. M. Lane Where a fillet is necessary often trouble can be avoided by putting a chill on the casting at that point, so as to chill the larger body of metal at the same time that the rest of the casting is cooling. The writer knows of several cases in which it has been done successfully in air compressor work.

2 In reply to Mr. Williams' remark about putting in a riser, if bronze work is being dealt with, a shrink boss will correct the difficulty.

3 There is a very marked difference between cast iron and most of the alloys. The alloys set in a mold with a flexible skin, and that skin bends or yields as shrinkage takes place. The writer split some shrink bosses recently to see if there were any blowholes, cavities

or pockets inside. None whatever were found, but the bosses showed great deformation on the outside. This will occur in bronze and in a great many of the copper alloys, but in cast iron or steel, the skin is not flexible to the same extent, although it is more so in steel than in cast iron. It sets at once and takes its permanent form; then the shrinkage is not toward the core, but toward the skin, and instead of the hollow occurring on the outside, as in bronze castings, it occurs on the inside as a shrink hole. Any substance on the inside expanding, *like gas*, causes a blowhole and will necessarily have a smooth surface; but if the hole is caused by shrinkage it will have an angular rough surface. There is no doubt about what causes these holes. If the hole is caused by dirt being in the casting, the dirt is there when the casting is broken open.

4 A flywheel explosion, a few years ago, wrecked an entire building, and the writer took pains to obtain the piece of the wheel which had caused the most damage. The wheel was provided with a very heavy fillet at the outer end of each arm, in which was a hole large enough to lay the hand in, indicating a tremendous shrinkage in the casting at that point. It was a band flywheel, and the rim of the wheel in the center was about four inches in thickness and about 2½ inches at the outside, and with nearly a 40-inch face. It had quite a heavy rib around the center, but there was this enormous pocket right where the heavy fillets joined. The arms were bolted on. Other flywheel manufacturers have had the same experience, and the flywheel design has been changed in a number of instances in order to omit the fillet.

5 Here is another case: In the anthracite coal region a great deal of trouble was found with the partition in the pumps between the dead ends, that is, the dead-end partition between the two plungers that work toward each other. That partition is sometimes 14 inches in diameter and it must withstand a pressure of possibly 800 pounds to the square inch, so that it requires a considerable thickness of metal. The matter of clearance is of no account. The partition was eaten right through by the mine water, so that in a short time the pump was chugging the water back and forth, and the question was raised as to why it was eaten through. The writer broke up some of the material and photographed the pieces. There were large pockets in them. By breaking a comparatively new casting, it was found that the heavy fillet and the extra thick metal had resulted in an open porous structure through which the acid water had eaten a passage of five or six square inches of area.

6 The difficulty was overcome in the following manner. The bore of the pump cylinder was about an inch and a quarter thick. A 14-inch partition was built up of one-inch metal, stiffened by two-inch ribs one inch thick. By dividing the strengthening metal and the partition into one-inch metal so that it cooled quickly, the heavy fillet was dispensed with and a casting was obtained which lasted four or five times as long.

7 A fillet may be altogether too thick, and in a great many cases it should be dispensed with almost entirely, the design of the flywheel being changed in such a way as to get as uniform metal as possible, and the strength secured by some other method.

MR. J. E. JOHNSON, JR. The size of a fillet is a matter that depends a great deal upon the amount of additional metal. It is a well known fact that a thick place in a casting will feed the surrounding parts of the casting. That is what causes shrinkages, or cavities. It makes a sponge of metal at these portions. The great majority of construction engineers do not realize its importance.

2 In confirmation of Mr. Lane's statement concerning shrinkage cavities, the writer once had made a pulley three feet in diameter. having six arms and a very thin rim about two inches wide. It was flanged, and the flanges being low, the rim had been cast solid and the center turned out to leave a rim about one-half an inch high on each side, leaving the metal in the rim proper quite thin, as it was desired to be very light, and as a result one could see on the face of the pulley the outline of the cross-section of each arm in a porous spongy metal much darker in shade than the rest. It was not a serious weakness for the purpose for which the pulley was intended. It is still in service after several years use, but it was a clear indication of the effect which is practically always produced by a change in section, or the junction of two sections of a casting.

3 Just as much harm can be done by doing without fillets where they are needed as by putting them in where they are not needed.

4 Every one is probably familiar with the case that Whitworth illustrated, years ago, of a hydraulic cylinder about a foot in diameter inside and with six inches of thickness of metal. He made them with square bottoms, and the bottom simply shot out as a conical plug, running from the inside corner to the outside corner, because the crystallization from the cylindrical portion was at right angles to that portion, and the crystallization of the bottom portion was at right angles to that. Where these two lines of crystals met at a sharp

angle they did not unite properly, and while the metal was not separated on that line it had very little strength, and the castings gave way under pressure. Then others were made exactly the same, but with the bottom hemispherical inside and out, making a continuous change in the direction of crystallization, with the result of correcting the trouble completely.

A VOLUMETRIC STUDY OF CAST IRON

By H. M. Lane, Published in Mid-November Proceedings

Mr. Edward N. Trump In chemical manufacturing, where cast iron vessels are used in the distillation of ammonia, it is found that carbonate of ammonia attacks the exposed iron parts in the interior of the vessel, and also the cast iron shell. A cast iron shell about eight or nine feet in diameter supporting 250 tons is sometimes found to diminish in thickness from 1½ inch to one-half inch and this half inch is sometimes eaten through, which makes it necessary to add ribs to insure against disaster. It is probable that some of the other ingredients besides iron are eaten out at the same time.

2 It seems that the volume of these impurities must be considerably changed since they unite with each other, and that the comparison which Mr. Lane made should have been on rather a different basis.

3 The relative diagrams, showing the volumes compared with the weight, should be made on the same outside sizes; that is to say, you should compare the areas representing the volumes with the same dimensions outside. It is much easier to show them to the eye in that way than to increase one diagram in general dimension, because the area representing each impurity in proportion to the general dimensions, is also increased. When the diagrams are of impurities of the same size, the increase of the volume by the dissolving of the iron is more readily seen.

Mr. A. E. Outerbridge, Jr.[1] Mr. Lane has shown in an interesting manner certain facts well known to metallurgical chemists. The following incident is of interest in connection with Mr. Lane's experience. In 1895 there was sent to the writer for examination and analysis a broken piece of a bilge strainer several years old, taken from the hold of a steamship plying between the West Indies and New York, carrying sugar and molasses, together with general

[1]Non-member, with Wm. Sellers & Co., Philadelphia, Pa.

cargoes. The specimen closely resembled in appearance a piece of cast iron stove plate, through which many holes, about one-fourth inch in diameter, had been drilled. The material was soft enough to whittle with a knife, was little heavier than hardwood and when rubbed on a piece of white paper left a black streak; its specific gravity was 1.80 or about one-fourth the density of ordinary cast iron.

2 On grinding a small portion in a mortar and boiling in acids, a very small quantity of iron was found. Incineration in a platinum crucible of the insoluble material caused a loss of the major portion, which consisted of carbon, the residue being a reddish white powder, mainly silica tinged with iron rust. The complete analysis showed that the strainer had been made of cast iron, that the weak acids of the bilge water had very slowly dissolved the iron, leaving a shell or skeleton, composed chiefly of the so-called metalloids, carbon and silicon, found in ordinary gray cast iron.

3 A somewhat similar case occurred more recently at a large oil refinery, where the picks of some laborers struck right through the cast iron pipe that carried off the sludge acid, the iron having been slowly dissolved away.

4 In analyzing "silvery pig iron," containing say 6 per cent of silicon, it is customary, after removing the iron, manganese, sulphur and phosphorus by acid, to collect the residue, consisting of carbon and silicon, on a filter paper which is dried and then burned in a platinum crucible. All of the carbon is consumed, leaving a pure white powder of silica. If this powder is placed on a piece of paper, and a fresh quantity of the fine cast iron drillings, of the same weight as the original sample used for the analysis, be placed in juxtaposition with the silica it will be observed that the white silica (representing 6 per cent of silicon in the iron) is quite as bulky in appearance as the cast iron drillings. This is due partly to low specific gravity of silicon and partly to the fact that it absorbed practically its own weight of oxygen from the air, being changed into silicon-oxid or silica, an exceedingly light and bulky material.

MR. J. E. JOHNSON, JR. I think Mr. Lane is entirely in error in very many of his statements, especially in regard to what he has said about malleable castings. In malleable castings, the carbon is removed from the external layers by the oxidizing influence of the oxid in which the castings are packed for annealing. This influence does not penetrate very deeply, and in consequence the only good part of the malleable casting is its surface layer. It is almost universally

known that if the malleable casting is finished in such a way as to remove a considerable proportion of this surface layer, the casting so treated becomes rotten and almost worthless. The statement that the carbon leaves cavities like worm holes when it has been removed in this way, is not correct. Carbon can go through iron by transfusion either into or out of the iron without leaving any trace of its havin passed through, any more than there would be of water having gon through blotting paper from a wet surface to a dry one. Take the case of the cementation process of manufacturing cast steel. Wrought iron bars are put in fine carbon and heated for several days, with the result that they absorb 1 per cent or more of carbon. Now I do not believe that Mr. Lane will undertake to prove that he can show the worm holes through which the carbon passed to the central part in this material.

2 It seems to me that this whole matter of volumetric study is absolutely wrong and calculated to cause speculations which can only lead to serious error except in so far as it concerns the specific gravity of ordinary cast iron, in which the graphite swells up the mass as a whole by depositing in the molecular spaces and increasing them to very considerable dimensions, thereby diminishing the specific gravity of the iron as a whole to a much lower figure than that for solid iron, not graphitic. This has been understood for a century and needs no comment.

3 The manganese, sulphur, silicon, and phosphorus, we know to exist only in the combined condition; and we further know that the specific gravity of most of the combinations is about as great as that of iron itself, so that their effect on the volume of the iron may be ignored absolutely, for all practical purposes.

Prof. R. C. H. Heck In Mr. Lane's arithmetical operation of changing from proportion by weight to proportion by volume, there is an error in method which makes the "impurities" bulk too large. The error consists in not using the proper base for the volume percentages, and the correct transformation can best be shown by an example, taking the first analysis in Table 1 of the paper. In the subjoined tabular arrangement, the original figures are in roman type, the changes or additions by the writer are in italics.

2 The idea is simply this: We start with 100 units by weight of the mixture of iron and other elements. Using the "volume factor," we change to a volume-measure in which the unit-weight quantity of iron is also the unit of volume; and in the particular case here

worked out there are 128.8 such parts by volume. This number is the base to be used in computing percentages by volume.

3 This error does not affect the character or detract from the value and interest of the ideas which Mr. Lane presents, but merely modifies the numerical (and graphical) values involved, in a manner which ought not to be allowed to pass without correction.

NO. 2 FOUNDRY IRON

	Per cent *by weight*	Factor	*Parts by weight*	*Per cent by volume*
Si	2.00	4.00	8.00	*6.21*
S	0.04	4.07	0.16	*0.14*
P	0.70	4.44	3.11	*2.42*
Mn	0.70	1.01	0.70	*0.54*
C	3.50	6.79	23.76	*18.44*
Total *Impurities*	6.94		35.73	*27.75*
Fe	*93.06*	*1.00*	*93.06*	*72.25*
Total	*100.00*		*128.79*	*100.00*

Figures in above table in italics are quoted.

SOME LIMITATIONS OF THE MOLDING MACHINE

By E. H. Mumford, Published in Mid-November Proceedings

Mr. Ronceray Mr. Mumford mentioned exceptional cases where it might be necessary to provide for double-ramming, that is, ramming deep pockets from the mold face independently, and his presentation of the case, according to my experience, is characteristic of the condition of machine molding in this country. In this country the power pressing molding machine has been applied especially to shallow castings. It has been quite a different proposition on the other side of the ocean, governed largely I suppose, by the peculiar requirements of the trade. There is very little repetition work there, while on the contrary there is considerable of it here. We have perhaps more exacting conditions to meet; that is why no doubt, it has been found necessasy to ram deep parts in the mold; and this is the reason for the presence of what we call "double-ramming."

2 It is well understood that after the mold has been rammed from the top, the stool is given additional pressure from the bottom. This method is used for special cases. It is not for general ramming around deep patterns.

3 This occasion gives me an opportunity to describe a new molding machine, illustrated in Fig. 1 and Fig. 2. Take for instance, patterns shown in Fig. 1, for a projectile, which shows the usual shape. It is expedient to have several projectiles in the mold, but only two will be shown which will be sufficient for the demonstration. It is well known the difficulty in trying to ram sand around too small

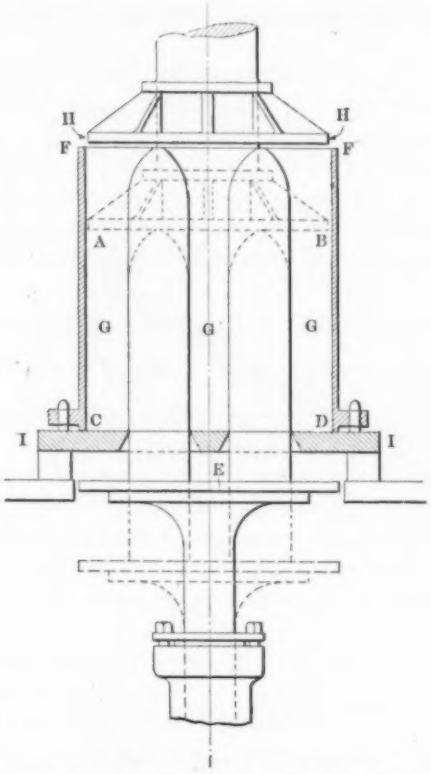

FIG. 1 A PATTERN FOR A PROJECTILE

pieces like those discribed. The problem has been solved in this way; the patterns have been made longer than necessary for the mold itself, *ABCD* as shown, and they are mounted on a plate *E* on a piston which has a vertical motion. Place sand in the flask, and sand frame up to the level *FF*, the sand to be rammed in, as on an ordinary molding machine, except that in an ordinary machine it is evident the sand would not be rammed at *GGG*, even if the patterns were

fixed at the position shown by the dotted lines, and sand rammed over them, the friction of the sand would interfere with the ramming. As shown in the sketch, the descent of the ramming plate *HH* carries patterns and sand down together until checked at the surface *AB* by an adjustable stop and a perfectly rammed check is made. When sand is rammed over the patterns, and the patterns are pushed down through the stripping plate *II* by other means than actual contact with the patterns themselves, so leaving sand over them, a complete

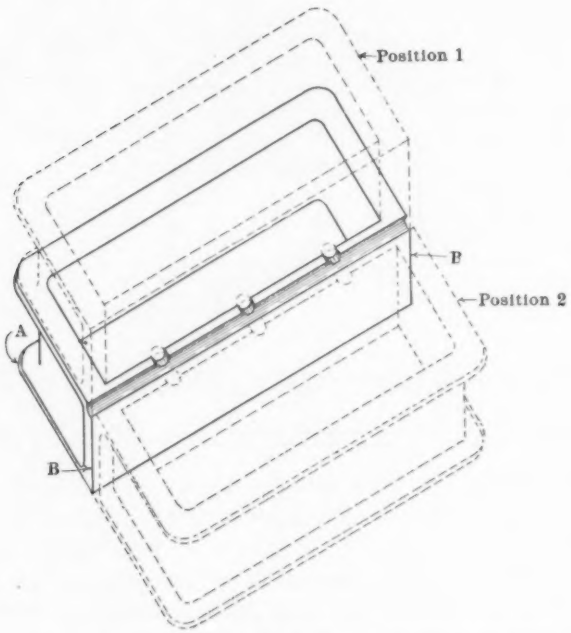

FIG. 2 A SPECIAL SET OF PATTERN-MAKING FLASKS

half mold, instead of a check, is formed. This method has been tried on difficult work, and it is a very effective way to ram deep sand without hand work.

4 The author mentions that the product of stripping pattern plates requires great accuracy. There are stripping plates on which the cope and the drag part of the pattern are put along side of each other. Great accuracy is obtained by a special set of pattern making flasks, as shown in Fig. 2.

5 *A* is one-half of an ordinary flask, cut in the middle, and flanges and a fourth side are put on at *BB* and finished with great accuracy.

What Mr. Mumford has called a foundry jig comprises two of these half flasks, and a single cope flask.

6 Placing the second half of the flask over the first, and ramming it up, as a cope mold on any patterns lying in the joint, the planed sides being held accurately in the same plane by bolts and dowels, in position 1, and then lifting this cope and rolling it back into position 2, we obtain a duplex drag mold in which every part of a mold in one half is absolutely opposite every homologous part of the mold in the other.

7 Over this duplex drag a one-piece cope mold, which has been separately rammed up, is placed upon a frame which constitutes a special check of small depth, and the pattern plate run in this three part mold will leave the reversing principle embodied in it by virtue of its method of manufacture.

8 Reversing stripping plates are made in the same way except that they are made in the joint itself without the check frame.

PATTERNS FOR REPETITION WORK

By E. H. Berry, Published in Mid-October Proceedings

Mr. H. M. Lane The Becker-Brainerd Company, of Hyde Park, Massachusetts, a couple of years ago, placed the entire planning of the work of foundry equipment in the hands of the engineering force. The time has come when engineers must appear in the foundry in very large numbers, because wherever a sufficient number of duplicate castings, requiring not only drawings but finished parts, are to be made, results cannot be predicted if any latitude be given the pattern maker.

2 This brings up an interesting point observed in the works at Ilion which was the installation of a safety valve to limit the pressure in the holding mechanism of the machine.

3 It was further noticed that these people hold very closely to their gages. The men are held responsible for turning out castings to prescribed limits, and are not paid for them unless the castings correspond to these limits. The result is, that the men are careful because it is a matter of dollars and cents to them. Both of these factors are tending to produce very accurate work.

4 Another interesting observation was that when patterns intended for hand work are placed in the molding machine, the castings sometimes turn out too light and it is necessary to place bands on the outside.

FOUNDRY BLOWER PRACTICE

By W. B. Snow, Published in Mid-October Proceedings

Prof. A. L. Williston Referring to the curves shown in Fig. 2, I would like to ask the author of the paper if he will state what size and character of a fan these curves are intended to cover, and the corresponding range of pressures and velocities. In the absence of such information, some of us might attempt to apply the conclusions drawn from them to cases so far different from those prevailing in the tests on which these curves are based, as to run the risk of being greatly misled.

2 In attempting myself to draw curves of this sort from different fan experiments, I have found that the curves differ radically according to the different sizes and character of the fans and the conditions under which they are used, and that the very greatest care is necessary whenever the comparison is made between the performances of two different fans, in order to be sure that similarity of conditions is sufficient to warrant the comparison. If the author of the paper, therefore, can add some definite data on this subject he will make his paper of still more value to the members of the Society.

Mr. Sanford A. Moss In the mathematical introduction with which Mr. Snow prefaces his paper, Table 1 gives computations from an approximate formula which are carried to a much greater number of significant figures than is warranted. The formula 4, which Mr. Snow gives, is the correct formula for very small pressure differences. It assumes an incompressible fluid. This formula is practically correct for pressures up to two ounces per square inch. For greater pressures, a correction must be made to allow for the fact that the density of the fluid changes during expansion. This subject was fully discussed in the American Machinist of September 20 and 27, 1906.

2 The formula which Mr. Snow uses is exactly equivalent to formula 11 of case 5. The proper formula for pressures above two ounces is formula 7 or 9 of case 4. For instance, for the pressure of 20 ounces per square inch, the velocity should be 376 feet per second instead of 370, a difference of nearly 2 per cent. This difference is, of course, not significant for ordinary work and the figures given by Mr. Snow are a close approximation. However, it is not proper under the circumstances to carry the figures to the number of decimal places given.

3 For the higher pressures given in Mr. Snow's table, from six to 20 ounces, an almost exact value of velocity can be obtained by multiplying the quantity within the radical of formula 4 by the expression $\left(1 + \frac{x}{2k}\right)$ where k is the ratio of specific heats of air and is such that $\frac{1}{k} = 0.711$ and x is equal to $\frac{p}{235 + p}$, using Mr. Snow's notation, where p is the pressure in ounces above atmosphere. For pressures above 20 ounces, the exact formula must be used, as discussed in the references previously cited. When computed by the correct formula, the velocities given by Mr. Snow would have the following values:

Pressure oz. per sq. in.	Velocity ft. per sec.
3	148.9
4	171.7
5	191.6
6	209.7
7	226.2
8	241.5
9	255.6
10	269.2
11	282.0
12	294.7
13	307.0
14	316.7
15	327.5
16	337.5
17	348.0
18	357.5
19	367.0
20	376.0

4 The other columns of the table have slight errors in a similar way. The first few figures given by Mr. Snow are, in all cases, practically correct, the only criticism being that the final figures are not warranted, and give a deceptive idea of their accuracy. A similar remark can be made of the constant 1 746 659 of formula 4. The circumstances do not warrant that this constant should be given to a greater degree of accuracy than 1 750 000.

Messrs. H. de B. Parsons and David C. Johnson Recently it was necessary to work out a fan problem, and sufficient data could

not be obtained from the pamphlets and catalogues issued by the fan companies to calculate the size of fan needed under the given conditions. The writers therefore collected from many sources available information regarding the subject, and worked out the following simple formulae and curves, which, it is believed, will enable one to answer most questions which might arise regarding the capacity, speed, horse power, etc., of blowers and disc fans intended for ordinary use.

2 The formulae are to be used for calculating the size and horse power of fans, and are not to be used for designing and calculating the dimensions of the various parts.

3 The formulae are not original, nor is it claimed that they would be accurate under all conditions, although they have been checked with many fans in actual operation, and in all of these cases have given close results. The formulae for the blower type gives closer results than those for the disc type.

4 In the case of disc fans it is very hard to get formulae that will cover all cases, as a slight difference in setting or arrangement will materially affect the result.

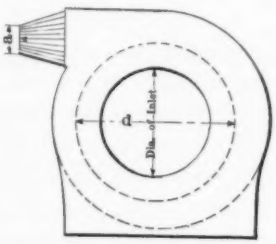

FIG. 1 FAN WHEEL WITH PERIPHERAL DISCHARGE

Calculations for capacity, revolutions and brake horse power:

Q = air discharged in cubic feet per minute.
d = diameter of wheel in feet.
w = width of wheel at tip of blades in feet.
R = revolutions per minute.
V = peripheral velocity of wheel in feet per minute.
v' = theoretical velocity of air in feet per minute.
v = actual velocity of air in feet per minute.
D = density of air in pounds per cubic foot.
B = brake horse power to drive wheel.
a = effective area of discharge or "blast area" in square feet.

h = head of air in feet.
G = acceleration per minute due to gravity = g 32.2 (in feet per second) x $\overline{60}^2$ = 11 577 600 feet.
p = pressure of air in pounds per square foot.
K = constant for different temperatures.

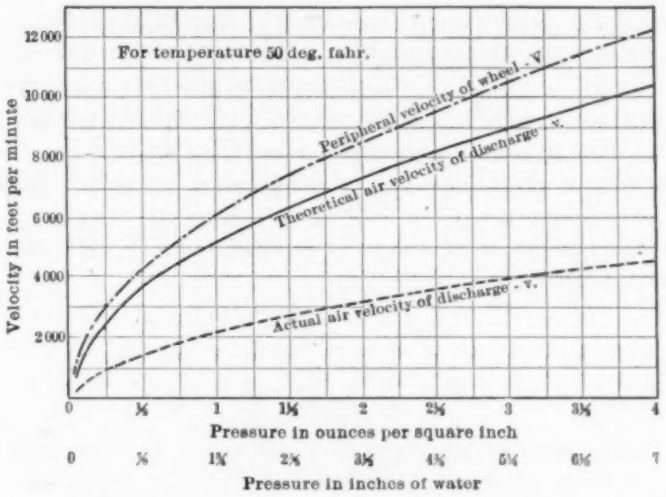

FIG. 2 THEORETICAL AIR VELOCITY CURVE OBTAINED FROM THE FORMULA $V = \sqrt{2Ah} = \sqrt{2A\frac{p}{D}}$

5 The above theoretical air velocity curve was obtained from the formulae

$$v' = \sqrt{2Gh} = \sqrt{2G\frac{p}{D}}$$

D being density of dry air at 50 degrees fahr. = 0.0778 pounds.

6 The peripheral velocity of wheel and actual velocity of discharge curves were calculated from the following formulae obtained by experiment.

$$V = 1.17\ v' \text{ and } v = 0.43\ v'$$

7 The above curves are for dry air at 50 degrees fahr. The velocities vary as the square root of the reciprocal of the densities.

8 At any temperature fahr., the velocities = K times velocity at 50 degrees fahr. Therefore use corrected velocities corresponding to the temperature.

VALUES OF K FOR VARYING TEMPERATURES

Degrees Fahrenheit	K	Degrees Fahrenheit	K	Degrees Fahrenheit	K
30 =	0.98	200 =	1.14	400 =	1.30
50 =	1.00	250 =	1.18	450 =	1.34
100 =	1.05	300 =	1.22	500 =	1.37
150 =	1.09	350 =	1.26	550 =	1.41

9 Usual maximum for $V = 6600$ feet per minimum, but should not exceed 7200 feet per minimum.

10 Width of blades at tip is usually made about $0.4 \times d$. Width of blades at widest part is made about $0.5 \times d$. When a small volume of air, discharged at high pressure, is desired, the width is less. When a large volume of air, discharge at low pressure, is desired, the width is greater.

11 The last two sentences are true when d or R is fixed, and V or discharge pressure is known.

$$a = \frac{Q}{V} \qquad Q = a \text{ times } V$$

$$R = \frac{V}{\pi d}$$

12 By experiment, approximately $a = w\,d \div 3$. Therefore, $a = 0.4d^2 \div 3$, from which d can be found

$$d = \sqrt{7.5\,a} = 2.74\ \sqrt{a}$$

13 Inlet area in square feet

$$= 0.00054\,Q \div \sqrt{\text{water pressure in inches}},$$

but should not exceed 40 per cent of disc area of side of wheel.

14 Outlet area in square feet = constant x inlet area.

For free discharge, the constant varies from 1.0 to 1.25.

For restricted discharge, as into ducts, the fan should be calculated for a pressure equal to that at outlet plus friction.

15 Theoretical brake horse power to drive fan wheel

$$= \frac{Q \times D \times v'^{-2}}{550\ (2G)}$$

B = theoretical horse power times 2. The efficiency being taken at 50 per cent.

DISC FAN

Calculations for capacity, revolutions and brake horse power:

Q = air discharged in cubic feet per minute, for "free discharge."

d = diameter of wheel in feet.
R = revolutions per minute.
V = peripheral velocity of wheel in feet per minute.
v' = theoretical velocity of air in feet per minute.
v = actual velocity of air in feet per minute.
D = density of air in pounds per cubic foot.
B = brake horse power to drive wheel.
a = effective area of discharge in square feet.
a' = non-effective area of discharge in square feet.
A = disc area of wheel in square feet.
G = acceleration per minute due to gravity = g (in feet per second) $\overline{60}^2$ = 11 577 600.
C = constant for brake horse power formulae = 106.

16 V should not exceed about 8500 feet per minute.

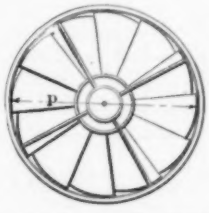

FIG. 3 DISC VENTILATING FAN

17 For restricted discharge or suction, Q becomes less because "slip" becomes greater. Approximately $Q = Av_1$ where $v_1 = v' - v_p$, in in which v_p is 40 per cent of the theoretical velocity due to the difference in pressure on opposite sides of the fan, due to the restriction. B is the same as for "free discharge."

$A = a + a'$
$a = 0.8\ A$
$a' = 0.2\ A$
$V = \pi\, d\, R$
$R = V \div \pi\, d$
v' = pitch ratio (V) per cent slip = 0.65 (V) 0.75
$v = 0.8\ v'$
$v' = 1.25\ v$
$v = 0.39\ V$
$Q = Av = av' = 0.8\ Av'$

18 The following approximate formulae, evolved by the writers have given good results:

$$B = \frac{Q \times D \times \overline{V}^{\frac{3}{2}}}{33\ 000\ (2\ G)} \text{ by } C \text{ in which } C = 106$$

19 For facility in using the above formula the following curve is given which gives the value of $\frac{\overline{velocity}^{\frac{3}{2}}}{2\ G}$ for corresponding values of velocities in feet per minute.

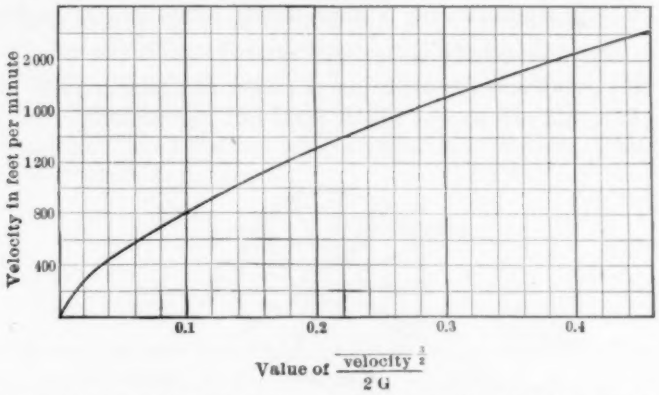

FIG. 4 CURVE GIVING THE VALUE OF $\frac{\overline{velocity}^{\frac{3}{2}}}{2G}$ FOR CORRESPONDING VALUES OF VELOCITIES IN FEET PER MINUTE

MR. E. N. TRUMP We have found the Venturi meter a very satisfactory means for measuring air. We made a series of tests to determine the efficiency of some of the positive blowers, and this meter gave measurements within less than 2 per cent error. I would say, also, that we have made tests at atmospheric pressure and as high as 250 pounds to the square inch, both meters being on the same pipe, and when we made allowance for the difference in temperature and pressure we found the volumes to compare very well.

MR. H. M. LANE In this paper some of the figures are in ounces, some are in inches of water and others are in pounds. The tables would prove of more assistance to engineers if the values were stated in terms of some one unit.

MR. T. S. BAILEY While it is true that the very complete series of tests undertaken by Mr. D. W. Tailor related to low pressure blowers only, his methods have been adopted by the Navy Department, and they are exceedingly valuable.

MESSRS. J. R. FORTUNE AND H. S. WELLS[1] The blowing equipment attached to our cupola, consisted originally of a No. 8 Sturtevant pressure blower which, as Mr. Snow has pointed out, varies its air delivery inversely with the resistance. In order to maintain a positive delivery of air, and thus increase the melting speed, it was decided to install a Sturtevant No. 11 high pressure blower which, while somewhat larger than is required at the present time, would be adequate for our contemplated new foundry, which will be equipped with 66-inch cupolas. Fig. 1 gives the internal dimensions of the present cupola.

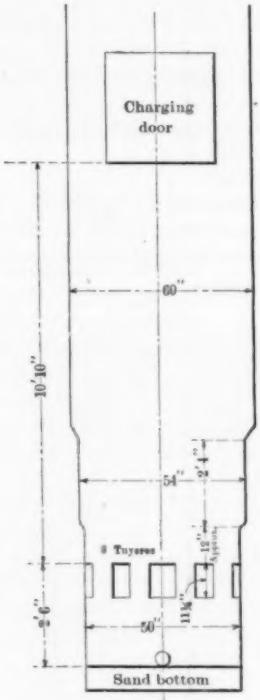

FIG. 1 SHOWING INTERNAL DIMENSIONS OF CUPOLA

2 The maximum melting rate, from iron down to blast off, with the old blower, was 8½ tons per hour.

3 Fig. 2 is a diagram of the blower revolutions, blast pressure and boiler pressure observed during the first heat with the new blower.

[1] Non-members, the Murphy Iron Works, Detroit, Mich.

At the right of the pressure diagram is a diagram of the cupola and the weights of charges of iron and coke. Table 1 contains the data secured during the trial. The proportion of coke to iron was kept the same as with the old blower and the cupola was unaltered.

TABLE 1

Total iron melted, tons	22.7
Melting rate (blast on to blast off), tons per hour	8.79
Melting rate (iron down to blast off), tons per hour	9.45
Time before iron comes after blast is on, minutes	11
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	19.81
Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	23.11
One pound coke melts how many pounds iron (including bed)	7.54
Blast pressure, ounces	11.60
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	*9.02
At 50 inches diameter cupola	7.96
Bottom of melting zone above top of tuyères, inches	12–18
Weight of iron layer is how many times weight of coke layer	10
Time between starting fire and starting blast, hours and minutes	2:30

*Taken before enlargement of tuyères.

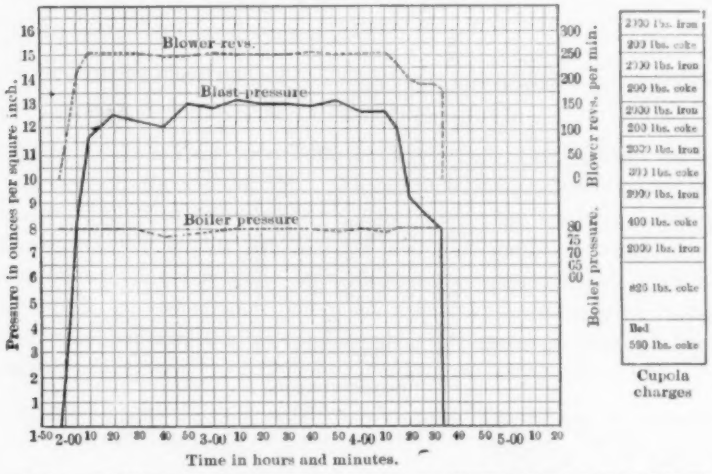

FIG. 2 CUPOLA TEST, STURTEVANT No. 11 HIGH PRESSURE BLOWER

4 The results of tests 2 and 3, which were made after enlarging the tuyère openings are given in Table 2 and Table 3; this change being made in the cupola to get in a greater amount of air without increasing the blast pressure.

TABLE 2

Total iron melted, tons	24
Melting rate (blast on to blast off), tons per hour	8.24
Melting rate (iron down to blast off), tons per hour	8.88
Time before iron comes after blast is on, minutes	13
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	18.61
Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	21.71
One pound coke melts how many pounds iron (including bed)	7.40
Blast pressure, ounces	10.63
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	*5.98
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyère, inches	10–12
Weight of iron layer is how many times weight of coke layer	10
Time between starting fire and starting blast, hours and minutes	2:30

*Bed too low.

TABLE 3

Total iron melted, tons	22.15
Melting rate (blast on to blast off), tons per hour	8.20
Melting rate (iron down to blast off), tons per hour	8.86
Time before iron comes after blast is on, minutes	12
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	18.55
Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	21.64
One pound coke melts how many pounds iron (including bed)	7.28
Blast pressure, ounces	10.00
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	*5.98
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyères, inches	10–02
Weight of iron layer is how many times weight of coke layer	10
Time between starting fire and starting blast, hours and minutes	2:30

*Bed too low.

5 Table 4 gives the particulars of a heat which was run after the coke bed had been increased.

TABLE 4

Total iron melted, tons	24.25
Melting rate (blast on to blast off), tons per hour	8.50
Melting rate (iron down to blast off), tons per hour	9.15
Time before iron comes after blast is on, minutes	12
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	19.17

Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	22.77
One pound coke melts how many pounds iron (including bed)	8.58
Blast pressure, ounces	9.47
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	*5.98
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyère, inches	12–14
Weight of iron layer is how many times weight of coke layer	13.33
Time between starting fire and starting blast, hours and minutes	2:30

*Coke charges decreased on account of iron being too hot.

6 It will be noted that while the melting speed was greater than for tests 2 and 3, it was below that of test 1. Upon decreasing the blast pressure, and *at the same time decreasing the amount of coke*, the melting speed was brought up to 9.15 tons per hour, tests 5, 6, 7, 8 and 9 were then made, the coke being decreased, while the blast pressure was increased each day, resulting in a decided increase in the melting speed. Tables 5, 6, 7, 8 and 9 give the data obtained from these tests.

TABLE 5

Total iron melted, tons	24.25
Melting rate (blast on to blast off), tons per hour	9.04
Melting rate (iron down to blast off), tons per hour	9.66
Time before iron comes after blast is on, minutes	10
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	20.25
Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	23.62
One pound coke melts how many pounds iron (including bed)	8.94
Blast pressure, ounces	9.80
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	5.98
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyères, inches	12–14
Weight of iron layer is how many times weight of coke layer	13.33
Time between starting fire and starting blast, hours and minutes	2:30

TABLE 6

Total iron melted, tons	22.65
Melting rate (blast on to blast off), tons per hour	9.39
Melting rate (iron down to blast off), tons per hour	10.24
Time before iron comes after blast is on, minutes	12
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	21.44

Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	25.01
One pound coke melts how many pounds iron (including bed)	8.71
Blast pressure, ounces	9.86
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	5.96
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyère, inches	10–14
Weight of iron layer is how many times weight of coke layer	13.33
Time between starting fire and starting blast, hours and minutes	2:30

TABLE 7

Total iron melted, tons	24
Melting rate (blast on to blast off), tons per hour	9.60
Melting rate (iron down to blast off), tons per hour	10.43
Time before iron comes after blast is on, minutes	12
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	21.82
Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	25.45
One pound coke melts how many pounds iron (including bed)	9.02
Blast pressure, ounces	10.00
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	5.98
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyères, inches	10–14
Weight of iron layer is how many times weight of coke layer	13.33
Time between starting fire and starting blast, hours and minutes	2:30

TABLE 8

Total iron melted, tons	20.30
Melting rate (blast on to blast off), tons per hour	9.75
Melting rate (iron down to blast off), tons per hour	10.91
Time before iron comes after blast is on, minutes	13
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	22.95
Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	26.77
One pound coke melts how many pounds iron (including bed)	9.02
Blast pressure, ounces	10.13
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	5.98
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyères, inches	10–12
Weight of iron layer is how many times weight of coke layer	14.28
Time between starting fire and starting blast, hours and minutes	2:15

TABLE 9

Total iron melted, tons	23.85
Melting rate (blast on to blast off), tons per hour	10.36
Melting rate (iron down to blast off), tons per hour	11.35
Time before iron comes after blast is on, minutes	12
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	23.77
Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	27.73
One pound coke melts how many pounds iron (including bed)	10.02
Blast pressure, ounces	10.55
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	*5.98
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyères, inches	10–12
Weight of iron layer is how many times weight of coke layer	15.38
Time between starting fire and starting blast, hours and minutes	2:45

* Iron too dull on account of too small coke charges.

7 During test 9, however, it was noticed that the iron was not at the proper temperature, so for the next test, 10, the coke was increased without altering the blast pressure. This resulted in a decreased melt per hour.

TABLE 10

Total iron melted, tons	22.35
Melting rate (blast on to blast off), tons per hour	10.25
Melting rate (iron down to blast off), tons per hour	11.17
Time before iron comes after blast is on, minutes	11
Iron melted per minute per square foot cupola area, based on iron down to blast off (54 inches diameter), pounds	23.39
Iron melted per minute per square foot cupola area, based on iron down to blast off (50 inches diameter), pounds	27.29
One pound coke melts how many pounds iron (including bed)	9.49
Blast pressure, ounces	10.55
Cupola area is how many times tuyère area (small end):	
At 54 inches diameter cupola	*5.98
At 50 inches diameter cupola	5.13
Bottom of melting zone above top of tuyères, inches	10–12
Weight of iron layer is how many times weight of coke layer	14.28
Time between starting fire and starting blast, hours and minutes	2:30

* Iron rather dull, coke charge should be increased from 140 to 150 pounds.

8 The remainder of the tests which have been made have not been tabulated, but it has been found that a coke charge of 150 pounds, with a blast pressure of $10\frac{1}{2}$ ounces results in a melt of between 11

and 11½ tons per hour, the iron coming down at the proper temperature.

9 We believe that the changes which are responsible for the increase of our melting rate, were the enlargement of the tuyère openings and the decrease of our coke charges. The enlargement of the tuyère openings making it possible for us to get the necessary air into the cupola without burning more coal under our boiler, and the decrease of the coke charges resulting in a saving of one-half ton per each 25 tons of iron melted.

10 A close study of cupola action indicates at once why an excess of coke decreases the melting rate. Iron in the cupola is melted in a fixed zone, the first charge of iron above the bed being melted by burning coke in the bed. As this iron is melted, the charge of coke above it descends and restores to the bed the amount which has been burned away. If there is too much coke in the charge, the iron is held above the melting zone above referred to, and the excess coke must be burned away before it can be melted and this of course decreases the economy and the melting speed.

FOUNDRY CUPOLA AND IRON MIXTURES

By W. J. Keep, Published in November Proceedings

Mr. E. H. Foster In an issue of the Engineer of London, March 23, 1900, is a description of a cupola liner which was later patented in the United States under serial number 651 703.

2 While visiting a foundry in London where the liner was developed, the owner took me up to the charging floor of a cupola which was being cleaned, and asked me to guess the material forming the lining. On looking down through the charging door the internal surface of the cupola was perfectly clean, free from any projections, of a grayish-white color, and divided off into squares resembling tile. It was difficult to tell just what the material of the lining was. It resembled somewhat an enameled tile in appearance and was much too clean and unbroken to be fireclay.

3 As a matter of fact the lining was made of cast iron, built up in hollow blocks of radial brick form. It was claimed that it had been in use for 19 months, and that the cupola, which was a No. 5 Stewart Rapid, was formerly rated at four tons per hour, but that after lining with the cast iron hollow bricks five tons per hour were easily gotten out of it.

4 Besides increase of capacity there was a saving in time for repairs, also in the use of ganister. The perfectly smooth surface, prevents all tendency to hang-up, and after each run the surface can be swept clean. Furthermore, there is no danger of such a lining becoming broken by the charging process. It seems that such a lining can be easily applied to almost any type of cupola.

5 Several cupolas in England are so lined, but I do not know of any in this country.

PROF. W. W. BIRD It has been the writer's experience that many questions are asked in regard to the use of scrap in foundry mixtures. One point that has not been brought out is this: we understand that silicon is used in foundry mixtures for the purpose of making castings soft for machining. In the paper it is stated that it is best to select the scrap according to the thickness of the castings to be made. In selecting scrap it is a very simple matter to specify that the material should give some evidence of having been machined, and that, if this evidence is present, then the percentage of silicon must be somewhere near the proper amount for that thickness. This test should be included in the specifications. Then we will have something that will correspond to the chemical analysis.

A FOUNDRY FOR BENCH WORK

BY W. J. KEEP AND EMMET DWYER, PUBLISHED IN MID-OCTOBER PROCEEDINGS

MR. E. H. MUMFORD The authors have mentioned that they have a mezzanine floor and put the machines under, instead of on it. That is especially interesting in view of the fact that just now a modification of what has come to be known as the Crane system of placing machines and everything else on the upper floors, and dropping castings and sand down through perhaps several floors, is being exploited in a number of new foundries. I would like to know their reason for putting the machines *under* the mezzanine floor.

MOLDING SAND

BY A. E. OUTERBRIDGE,[1] PUBLISHED IN OCTOBER PROCEEDINGS

MR. H. M. LANE Mr. Mumford has brought out a point in regard to rubbing the alumina into the sharp silica to make the sand stronger which reminds me of a recent experience at a foundry in Ohio.

[1] Non-member, with Wm. Sellers & Co., Philadelphia, Pa.

2 The foundryman was using a sharp, bank sand, mixed with a small amount that contained a little natural bond and a certain amount of core binder—a dry binder in this case—and had been discarding 50 per cent of the core sand and using about 15 to 20 per cent of the natural bond to make the mixture strong enough. He designed and put in a mill, which is essentially a clay grinding mill, and grinds his core material, using 90 per cent of the old core sand. He finds that in the large cores the binder in the interior of the cores has not been so badly burned out but that it still retains a great deal of bonding quality, so that he now uses only half of the binder. He has thrown out all of the expensive imported sand and uses the local bank sand. He formerly had a power riddle and four men working all day to supply his foundry with core sand. Today he has a night force to haul the sand out, as formerly, but he has two men working less than half a day to supply the entire foundry with core sand. He formerly had to wheel the burnt core sand some 450 feet away from the foundry and dump it over the bank. Now he wheels it through a partition into the next room.

3 Counting the saving in time and labor and the saving in using a cheaper grade of sand, he figures that he has made over $2000 a year. In other words, he will pay for his mill in eight or ten months.

4 The foundry referred to is that of the Falls River and Machine Company, at Cuyahoga Falls, Ohio, and the mill was designed by Geo. H. Wadsworth.

5 In regard to the Worthington practice of grinding the bond in thoroughly, they found that they got the bond on the corners of the sand, if I may so express it, thus giving a very porous core, while if it is mixed in by hand they get a much denser core. In other words, the venting of pockets and chambers gives less trouble than formerly because less compound was used and the pores were not being stopped up. They have been able to cast a great many very thin jackets in this way without any trouble at all even though vent passages were cut.

Mr. E. H. Mumford At a large foundry making steam pumps all the sand used in the smallest port cores is run through a mill, and with very good result. Nothing but raw linseed oil is used as a binder. The ratio of sand to binder is from 60 to 90 to 1. This very large ratio of sand to binder is entirely due to the rubbing in of the binder upon the small crystals of silica.

CAR LIGHTING

By R. M. Dixon, Published in January Proceedings

Mr. W. Everett Ver Planck[1] The scheme of diffused lighting which Mr. Young has shown would light the whole ceiling brightly, affording no rest for the eye. In the system described below, developed by the company with which the writer is connected, a number of diffusing panels of an oval shape, as shown in Fig. 1 and Fig. 2, are fastened to the upper deck. These being limited in area, the remainder of the ceiling is comparatively dark. Under each diffuser is placed a row of lamps, which are shielded from the eye by a trans-

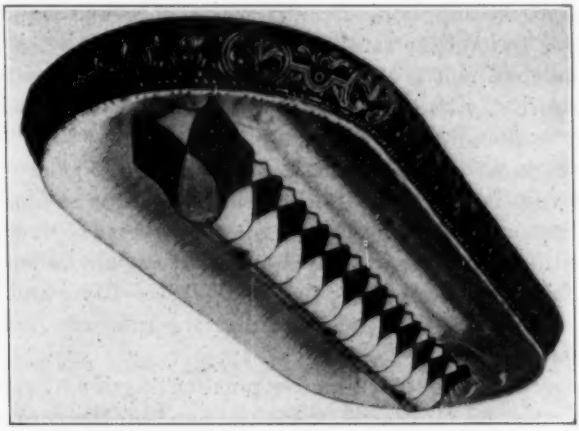

FIG. 1 SIX LIGHT TRAIN LIGHTING CEILING DIFFUSERS

lucent glass shade. The diffusing surface is so designed that it distributes a light of low intrinsic brilliancy evenly over the car, but leaves the ceiling comparatively dark to rest the eye. The lamps being entirely out of sight, clear lamps may be used with consequent increase of efficiency and life over frosted lamps.

2 This system has been successfully installed, makes a very attractive appearance, and affords satisfactory results.

3 With the "head end system" of electric train lighting, which is now used quite extensively, a steam driven prime mover, usually a turbine, is installed at the head end of the train, either in the baggage

[1] Railway Engineering Department, General Electric Company, Schenectady, N. Y.

car or on the locomotive itself. Current is sent back through the train by a three conductor cable, the extra circuit being run direct to the rear end of the train and then returning, with taps taken off at each car. In addition, some or all of the cars are equipped with storage batteries to carry the lights while the locomotives are being changed

4 The generating sets, now most popular, consist of small direct current generators of 15, 20 and 25 kilowatt capacity, driven by single stage Curtis turbines. The design is extremely simple and compact, with but two bearings, the turbine wheel being mounted on an

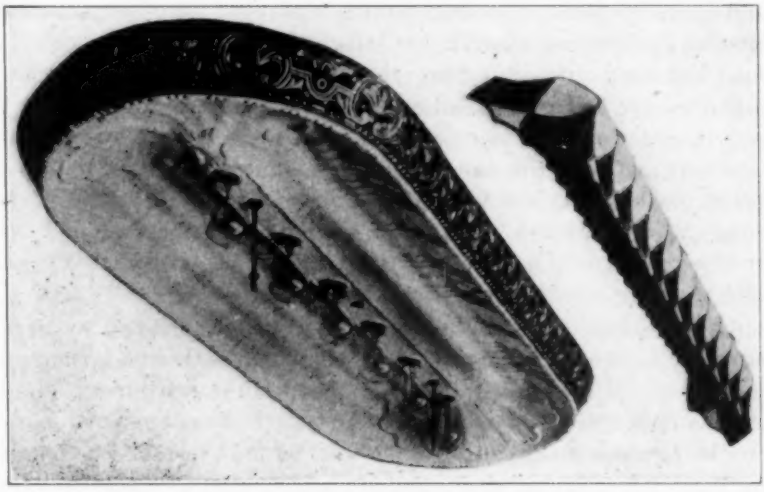

FIG. 2 SIX LIGHT TRAIN LIGHTING CEILING DIFFUSER

extension of the generator shaft. The speeds are moderate, 3600 to 4500 revolutions per minute, and cause no difficulties with the lubrication. Most of these sets are installed in the baggage car, where they occupy but little space and are looked after by the baggage men, in addition to their other duties; and on many roads they receive no extra compensation for this service. Steam from the locomotive is sent back through the regular steam heating hose, but the reducing valve on the boiler is set at 80 to 90 pounds, which is as high as the hose will stand. A second reducing valve, installed in the baggage car beyond the turbine, is set at the proper pressure for heating the train. When this system was first tried, more or less trouble was

experienced from the frequent bursting of the steam hose. This trouble has been largely overcome by using only new hose of first-class quality, and not allowing enginemen to turn back too high a pressure, that is over 90 pounds.

5 It is evident that the most desirable location for the turbine set is on the locomotive itself, where high pressure steam is available with its resulting improvements in the economy of the turbine, and where no interruptions can occur from hose failures. One of the principal eastern roads has long realized this, and has had a set mounted on top of the locomotive boiler in daily operation on a limited train, for more than three years. This set has proved itself extremely reliable, and since the first few months after it was put in service, there have been no shut downs chargeable to the machine itself. Although this road has been successfully operating about twenty sets in baggage cars for over three years, all extensions to the service will be with sets mounted on the locomotive. During the past year six more sets were installed, this time they were mounted cross wise on top of the smoke box. It is obvious that in such locations no attention can be given the machines while on the road, and it has been found that none is required. Careful inspection at terminals is all that is necessary to insure reliable operation.

6 Objections are sometimes raised to the "head-end system," on account of the inconvenience of the couplers between the cars, these being at present installed in the hood of the vestibule. Realizing the limitations of this location, at least two active attempts are now being made to develop a coupler which can be installed under the car platforms near the steam and air hose couplers. This will allow of their being connected by the train men who connect the steam and air. Such a coupler must be of very robust construction, able to stand a bombardment of ballast without injury, and not be affected by water, snow or ice. Furthermore the possibility of short circuit, when the coupler is open, must be reduced to a minimum.

7 As stated before, it is generally necessary to install one or more storage batteries on the train to carry the lights when locomotives are being changed. There is a great difference of opinion among railroad men as to just how much battery is required. Some roads install in every car a battery large enough to carry the light for several hours. Other roads install a battery on only one or two cars in the train and take care that the trains are made up so that a battery car will be located near each end. This allows placing the dining car

in the middle of the train without interrupting the lamp supply of either end. It would seem that the resulting large saving in first cost and maintenance of the batteries is well worth the extra trouble in making up the train.

8 In suburban service, and certain local runs, the locomotive may be attached to the train continuously while passengers are in the cars. For such service the batteries may be entirely eliminated. For cleaning cars in the yards, current for lighting may be obtained from a small stationary plant having circuits run to various points in the yard and plugging into the cars in the same manner as is often done for charging batteries. A system of this kind should compare very favorably with gas, both as to first cost and maintenance.

Summing up, the advantages of the "head end system" may be stated as follows

a Minimum battery capacity being required, first cost, maintenance and depreciation are less than with any other system of train lighting by electricity.

b The moving apparatus being of the fewest parts and of the simplest character, the reliability of this system is greater than any other, except of course the straight battery.

c The supply of current not being dependent on storage batteries, except for very short periods, rigid economy in the number of lights used is no longer necessary. This statement may be emphasized by quoting Mr. Ott in the discussion of his paper on train lighting before the Western Railway Club as follows:

> One of the strong features of the head-end system is that one is not restricted to a certain number of lights per car, and can use all the 16 candle power lamps needed. Additional coal at the locomotive will be the only added cost, and with a 25 kilowatt set, as quoted for the sample trains, this would be very small, as the nearer you approach the full rated load of the generator the lower will be the steam consumption per kilowatt hour.

Mr. B. P. Flory In deciding on a system of car lighting there are three principal points to consider. They are (*a*) first cost and cost of operation, (*b*) efficiency and (*c*) reliability.

2 For the three different systems in use—Pintsch gas, acetylene and electricity—Pintsch gas costs the least at first, acetylene comes a little higher and electricity the highest.

3 For the acetylene system, the writer considers the storage

tank system as the only one to use, and does not favor having a generator in a car, on account of the danger.

4 The electric installation, if an axle generating system is used, costs three or four times as much as the Pintsch gas or acetylene. The storage system costs a little more than the Pintsch gas or acetylene.

5 Regarding the cost of operation, the Pintsch gas can be procured at a price cheaper than acetylene, and if the railroad has its own charging plant and utilizes the by-products, such as hydrocarbons for tire heating and gas tar for firing up engines, the Pintsch gas can be produced at a very small cost.

6 The electric storage system is more expensive than either the Pintsch gas or acetylene.

7 With the axle generator system the cost of the coal and water required for turning the dynamos to generate the current and for pulling the extra weight of the generator system amounts to approximately five cents per car per hour.

8 The cost of repairs of the Pintsch gas and acetylene system are practically the same and are both very much less than any electrical installation.

9 The great trouble with the axle generator system has been its cost of repairs, and on a number of cars, on account of the liability of its failing, Pintsch gas has been installed as an auxiliary.

10 The Pintsch mantle system is a great improvement over the open-flame and gives very good illumination. The candle power is also produced with less consumption of gas than with the open-flame.

11 The cost of the mantles with this system, of course, is no small item. The Central Railroad of New Jersey has had this system in operation for nearly two years and has kept a careful record of the number of mantles used and find they have an average life of four months. With 5 four-flame lamps in a car it would mean that 60 mantles would be used per car per year.

12 The new single-flame mantle lamps recently made, of course, will decrease this consumption, and, with a mantle lasting the same length of time as on the four-flame lamps, only 15 mantles will be used per car per year.

13 Taken all in all, the Pintsch gas one-flame mantle lamp system seems to possess some advantage over the acetylene and electric systems, on account of first cost and cost of operation, and it gives equally as good illumination. There is no doubt at all but that the

electrical systems have a great many conveniences that the Pintsch gas or acetylene systems do not have, such as berth lights, electric fans, etc., but, on account of their high first cost, the cost of repairs and liability of failure it is doubtful if the axle generating system will come into general use, except where an auxiliary system is employed in connection with it.

MR. GEORGE L. FOWLER No doubt in the past there were advertising advantages properly credited to electric train lighting, and perhaps a small amount of patronage may have been due to having the trains lighted by electricity, or at least, public attention may have been directed to the railroad, which advertised the fact.

2 The first installations were disappointing—producing more or less of a red light, indicating that there was not sufficient current supplied owing to weak batteries.

3 In modern methods of car lighting only gas and electricity are considered—the oil lamp and the candle having gone out of use entirely. A satisfactory light can be furnished by either gas or electricity. The methods in use by the Pintsch Company in developing and using compressed gas made from petroleum oils offers an efficient system.

3 The other gas used is acetylene. The three methods of using acetylene are (*a*) by means of a generator in the car, (*b*) by means of an outside generator with the acetylene carried in storage tanks on the car, and (*c*), by compressing the acetylene as ordinary gas is compressed and placing it under the car.

4 The danger of placing a charge of compressed acetylene under a car body is obvious. A railroad officer states that there is only one kind of tank to hold compressed acetylene that could not be exploded by applying a torch. This is of double extra heavy pipe, covered with three inches of asbestos all the way around, and projecting from it a one-quarter inch pipe, sealed at one end. A torch applied to the end of that pipe, which is about 2½ feet from the end of the tank, could not explode it but would melt the top of the tank, and blow out a cloud of black smoke.

5 The acetylene system has the same danger on account of carrying compressed acetylene gas on the car. The writer has never heard of the explosion of an acetylene tank under a car, but knows that explosions have occurred with the compressing apparatus, due to some slight disarrangement of the apparatus. In a particular case in

mind, which was investigated by the writer, the side of the building was blown out.

6 As to putting carbide into a car, the National Board of Fire Underwriters, have a regulation covering this point which reads as follows:

> Installation of acetylene. Generating apparatus. Generating apparatus in or upon cars or other railway rolling stock or upon vessels, is not permitted. Properly safeguarded storage systems may be permitted if supplied with acetylene produced in generators constructed and installed in accordance with the rules and requirements of the National Board of Fire Underwriters.

7 That is the opinion of the Fire Underwriters in regard to the safety of applying an acetylene generating system in a car. The writer has, however, been unable to learn of any very serious damages to cars occupied by passengers due to the explosion of the acetylene generating apparatus. In two or three cases where explosions of the generating apparatus in the car has occurred only the attendants were present, and they fortunately escaped unhurt.

8 Service requirements of a carbide generator located in the car is very severe in the first place, the generator must be very simple; of such a character that it can be charged at one end of the line, make a round trip, and get back to the terminal and then be cared for by men who are competent and understand the vagaries and peculiarities of the apparatus. If such an apparatus is placed on a car dependent on the trainmen to take care of it en route, and if from any cause becomes exhausted, trouble is liable to result; also breakage of valves may occur causing the stopping of the flow of water to the carbide, or danger from excess pressure due to failure of the water valve to close, and lastly, the danger of freezing.

9 The railroad companies in the North using carbide apparatus claim they really have no trouble from freezing because they do not allow the cars to stand during cold weather without being coupled to the coachyard heating plant. If the cars are withdrawn from service they drain the apparatus entirely of water.

10 Certain parts of the mechanism in the car is of such a delicate nature, that the sludge coming down to a certain extent is apt to get into the valve and make a leakage which causes a loss of the gas, but, taken as a whole, the light failures in acetylene lighting are almost invariably due to neglect, or ignorance on the part of the trainmen and not primarily to any fault in the apparatus.

11 The arrangement or location of the lights in a car especially where electricity is used requires careful consideration. In one arrangement of lamps, which the writer recalls, there were two center cluster lights in the deck, and a row of unshaded berth lights extending around the car. The result was a glare which required the passengers to shade their eyes. Also there was a row of bare, incandescent lights on the deck rail, and the least raising of the eye produced an unpleasant glare. The uncomfortable effect was increased by the dark shadows on the deck above. A much more sensible arrangement would be to place the lights on brackets out from the deck rail, far enough to throw the light up against the deck, and yet low enough to illuminate underneath the side ceilings, also provide ground glass or opal shades, projecting far enough to hide the bottom of the bulb, preventing the naked light being seen and the eye from becoming strained, but when reading so arranged that the direct light of the unshaded bulb shines upon the paper.

12 In electric train lighting there has been so much experimental work and so many companies in the field, each claiming they had the best system, that many railroad companies are burdened with the very excess of systems offered. Perhaps two or three systems on the same road, and the men in charge know very little concerning these differences, resulting in confusion and lighting failures.

13 An electrician on a prominent railway, on which the axle lighting system is in use, considers that a car failure of 2 per cent is very efficient service and is about the best they can expect. Consider what that means! Out of every 100 cars, two cars are cut out of service entirely every night. Another road also employing the axle lighting system, stated that about two cars out of every 30 were reported as light failures every night. From the foregoing, it would seem, that in actual service, the axle systems show failures of from 2, to 5, 6, 7 and 8 per cent of the cars in service.

14 With the axle light on a car, a delicate piece of machinery is placed in an extremely bad location and in very unskilled hands. The frequent belt troubles, and other hazards, due to the severe conditions, interfere with the proper action of the generators. Another great difficulty with the axle lighting generator is that the generators are of too small capacity to give satisfactory service, 28, 30 or 35 ampere machines are installed, where 60 ampere are required, resulting in overtaxing the storage batteries.

15 In regard to the storage battery systems, they have the same battery troubles as are apparent in the case of the axle systems, only

in a greater degree, as the batteries required are larger and often not well adapted to the service. A superintendent of motive power using both the storage battery and axle light system, stated that he considered both an unmitigated nuisance, and an unwarranted expense to the road. He did not consider it even of enough value as an advertisement to justify continuance, and if he had his choice, he would go back to gas, in the use of which he would not have to count on 5 or 6 per cent of his cars being out of the train on account of lack of light.

16 The writer has had access to some figures, giving the actual cost of the axle and other train lighting systems under actual service conditions, which compared with cost, under similar conditions of the Pintsch mantel gas lamp, taking the latter as a basis, and calling it one, shows as follows: The acetone acetylene system would come about 2.12; the Pintsch flat flame, 3; the acetylene, 3.9; the storage battery, 8.38; the axle light, 8.97; and the dynamo or head end system, 9.16

MR. LAMAR LYNDON The writer has for some years been engaged in this class of work and believes that the present systems of lighting are in a transition stage and that eventually electricity will supplant all other methods of lighting railway trains; furthermore, trains will be lighted, by individual units, axle driven; but no system which carries a commutator, brusher, pole changer and a driving mechanism underneath the truck can ever be successful. A system can and will be designed in which all of these elements and disadvantageous factors will be eliminated, and when such a system is produced, that is absolutely reliable, possessing none of the troubles of the present axle lighting systems, no other system will be used and the question as to whether Pintsch or acetylene gas is the better, will be a discussion of the past.

2 It may be of interest to know that the Railway Mail Association has petitioned Congress to light all mail cars by electricity, because they consider any form of gas illumination dangerous. The data submitted to prove the danger of gas illumination are not known to the writer, but it is presumed they had good and sufficient reason for making such a petition. This bill, however, never passed.

MR. W. D. YOUNG In the adoption of a system of car lighting, the following factors, arranged in the order of their relative importance must be considered.

a Safety.
b Adaptability, involving ventilation, cooling, berthlights and location.
c Cost of operation.
d First cost.

2 The greater portion of railway cars will doubtless eventually be electrically lighted. Indirect lighting would add greatly to the comfort of the traveling public. The writer suggests a plan of indirect lighting, which is to place electric lights, of special form if necessary, at the intersection of the upper and lower decks, obscuring the direct rays of the light from the interior of the car proper, and, by means of reflectors, project the rays against the upper and lower decks, which should be especially treated.

3 In cars already constructed the intersecting molding could be modified, and new cars could easily be constructed to conform to this requirement. The cost of operating a car thus illuminated would be more, but its effect would be more pleasing. The illumination of the auditorium of the Engineering Societies Building furnishes a most successful example of indirect lighting.

MR. W. E. HALL The paper on "Car Lighting" and its discussion have brought to notice such of the systems as are now in use, either experimentally or in general service.

2 In comparing the results obtainable today with those that were in existence a decade ago, considerable progress must be noted, especially as to details, and in the effective interior lighting of the car.

3 The several systems described may be classed under three headings:

a Where each car has its own independent light generating plant. This includes, of those described in the discussion, the Safety Company carburetter, the electric generating apparatus of the United States Lighting and Heating Company and the acetylene, as presented by the Gold Company.

b The use of an illuminating product that is supplied to and stored in tanks or other carriers which are made a part of the car equipment. This includes the compressed illuminating and the Pintsch gas, the storage battery, etc.

4 Those under *a* and *b* make the lighting system for each car independent of every other car.

c Where there is one generating system for the train and not one for each car.

This covers the use of an engine and generator in the baggage car or on the steam locomotive or taking the current from the transmission line through an electric locomotive.

5 In reviewing the conditions to be met by an efficient system of train lighting, due consideration must be given to the relation of the problem to the transportation department, as well as to the mechanical features of the lighting apparatus.

With this in view its several phases are as follows:

SAFETY

6 The use of an inflammable material, such as illuminating and acetylene gas or carburetter wicking, saturated with gasolene, is undesirable. The breakage of any of the pipe connections in a wreck or in any other way that permits the escape or accumulation of the gas is, both directly and indirectly, dangerous. This applies as well to yards and stations as to cars. That an electric circuit for incandescent lamps is safer than the use of an inflammable material needs no argument.

EFFECTIVE LIGHTING OF THE CAR

7 The same candle power distributed uniformly by a number of small units is more effective lighting than when a less number is used. For instance, two 100 candle power units, one at each end of the car, will not be as effective as seven 32 incandescent lamps uniformly distributed throughout its length. It must not be inferred that the seven 32 lamps would be correspondingly more expensive than the two 100 candle power lamps. That is dependent upon many conditions. The concentration of the light, with mantles, gives a degree of intrinsic intensity that is objectionable.

8 We have, therefore, reason to expect a more effective lighting of the car by the use of a moderately low voltage incandescent lamp than by any of the gas systems described.

THE SYSTEM SHOULD REQUIRE THE MINIMUM OF ATTENTION

9 While discipline is the underlying principle governing successful management, it must be admitted that this can be more satisfactorily achieved with simplification than with complication.

10 With a generating or compressed gas system on each car, and assuming the average passenger train to consist of five cars, there are five units per train that must be looked after. They must be inspected and recharged when necessary. Any accumulated smudge or moisture, etc., must be removed. Any broken parts of the axle generating system, due to wear or tear or inherent defects, must be replaced. It is a burden upon the inspection and must result in more or less detention through oversight and neglect. The performance of all these details requires a good amount of time and labor and, when handling inflammable materials, of precaution and common sense.

11 With the electric train unit the care and attention required would be less than with any of the other systems. From experience with the air brake pump, the independently driven electric arc headlight (not that this is advanced as an argument in favor of this form of light for the head of the engine) and the steam heating system, the latter having a more or less perishable hose connection between the cars, it is evident that with an efficiently designed, independently driven, automatically controlled generator located on the locomotive that the failures from this part of such a system can be made practically nil.

12 For general service, as a transportation problem, the use of a steam driven generator located in the baggage car is simply impossible. It possessess no advantages but many disadvantages over the location of the generator on the locomotive. Its use is necessarily limited to special cases during a transition period.

COST

13 This should cover the installation and its corresponding depreciation, interest upon the original investment and the cost of operation. In the absence of reliable comparative figures covering all these items, the natural deductions would be as follows:

14 The gas systems under heading *a* would have a high cost for installation, a very low maintenance (barring the mantles) and a high cost of operation. The axle-driven electric method would probably in all these phases exceed that of any other system. This complica-

tion of running parts (made dust proof if you will and can), inaccessibly located and subjected to the dust, dirt, snow, etc., must result in large maintenance cost and a high cost of operation through replacement of broken and worn parts. It has been said that this system requires no power to operate it, but this statement, of course, is an error. Five generators having only the same aggregate power as one located on the locomotive, will consume considerably more power than where the current emanates from the one source. Further, the method of drive is less efficient and the mechanism is in operation whenever the car is in motion, day and night.

15 Those included under *b* would, on account of the compressor plant required, be high in installation, fair as to maintenance, and higher cost of operation than those under *a*. More or less efficiency of the gas is lost through compression. The storage battery is prohibitive on account of its present high cost and other self-evident reasons.

16 With the generator placed on the locomotive, the installation would be moderate and the maintenance and operating costs low.

17 Mr. Dixon says the cost of 95 to 100 candle power lamp with the Pintsch oil system is 1-1/16 cents per hour. What does this include? The only method of arriving at a satisfactory comparative conclusion is to have a detailed itemized cost reduced to a uniform basis of accounting. Every item of material and labor should be included. In the storage gas system the compressor plant should not be overlooked and in all gas systems the cost of such occasional explosions as may occur should be included.

SIMPLICITY

18 With the storage battery of sufficient life to cover the period between general repairs to the cars the train unit would require less attention than any of the other systems discussed. The inspection would consist of replacing a fuse occasionally, making the connection between the cars, or with the station or yard circuit when the engine is detached. Even the nicely designed lighting torch charged with wood alcohol is eliminated and incandescent lamps represent a standard product that may be found anywhere. The generator on the engine would be in the hands of the engine crew and of mechanics in the round house where such mechanism belongs.

19 However well the men may be trained and perfect the precautions taken, the care and handling of gasoline, carbide, compressed

gas or any other inflammable material under cars, around yards and stations requires, *per se*, more skill, care and labor and is accompanied with more danger than is possible with a low voltage electric circuit. In fact, all the foregoing points are more satisfactorily met by the use of an independently driven generator located on the locomotive than by any of the other systems. It will also follow nicely in sequence with the substitution of the electric in place of the steam locomotive in zones of great density and congestion.

20 With an independently driven generator on the locomotive, two possible objections arise and they should be carefully considered.

21 *First:* The power required to operate. A ten car train with 300 candle power per car obtained from 16 candle power 110 volt incandescent lamps requiring a total of, say 200 lamps, give at 10 lamps per horse power, a total of 20 horse power. This is on the assumption that all lamps in all the cars are in circuit at the same time—a condition that it would rarely, if ever, be called upon to meet. This does not, however, include the current shunted to the storage batteries. This would be exceedingly small as the amount of time that the batteries would be called upon, with electric connection along the station platforms and in the yards, would be but a small percentage of the total time that the lights are on. The maximum requirement would probably never exceed 30 horse power with the average probably less than half of this amount. This, therefore, cannot be considered an objection. Further, the new tungsten lamp has shown with a 40 candle power an efficiency of 1¼ watts per candle. This reduced to a 16 candle power gives 37 lamps per horse power. To cover losses in transmission, the lower efficiency of the 16 than the 40 power lamp, etc., and assuming 25 lamps per horse power gives a requirement for a ten car train, of 300 candle power each, only a total of eight horse power. Therefore, it promises that a ten kilowatt equipment on the engine will probably be more than ample for the maximum service that it would ever be called upon to meet. It also means a corresponding reduction in the size of storage battery that would be required.

22 *Second:* Is the adoption of the train unit in place of the car unit practicable? Many of the advocates of the car unit claim that the car, when isolated, will be without light. Let us see what has transpired along similar lines. When the use of steam from the locomotive for car heating was advocated the same objection to it was advanced. This was some 20 years ago and yet I doubt if anyone

has heard of any passengers being frozen to death or suffering any inconvenience on account of this isolation or for any other reason. This objection in the form of a possible contingency would probably have held back for many years the use of steam for heating had not the pressure from another direction made it necessary to ignore it. With steam heating no storage is provided other than the heat retained by the car. With the train unit electric method a storage may be used to take care of any emergency, such as isolation, switching at junction points, etc.

23 The carburetter lighting is practically a train unit because it depends upon the air from the brake system for its operation. But in addition, it includes, unfortunately, a lighting plant that requires a very inflammable material, as well as possessing other objections already mentioned. From Mr. Dixon's figures, the air capacity of the carburetter is about 14 cubit feet, and from his statement that the tank charged "will supply five 100 candle power lamps for at least 200 hours" the power requirement is no barrier. As the carburetter is used as a storage, however, the air pressure therein must be well maintained. This means that the check valve between the auxiliary reservoir and the carburetter should operate within a comparatively narrow range and, therefore, with a corresponding greater frequency. But we should not forget that the air brake is performing its work most admirably and that it is the best operating as well as safety appliance in existence. Molesting it is like railroad heresy and such practice should be discouraged. The arrangement for the air signal system is quite a different proposition.

24 Experience would seem to indicate that the advocates of the car unit system are adhering too closely to tradition. In fact, the more the subject of train lighting, with all its ramifications, is analyzed, the more clearly it points to the use of an independently driven, automatically controlled electric generator, located on the steam locomotive, as its most ready and satisfactory solution. It is the most direct and shortest cut. It is the safest, it permits of a more effective lighting of the cars, can be more easily handled by the train crews and inspectors with no imflammable material to be cared for and stored about the yards and stations. It promises lower cost of installation, maintenance and operation.

25 Has not car lighting been a laggard? We have had for many years braking, signaling and heating of cars by the train unit system. The results obtained from each tell their own story.

INDUSTRIAL EDUCATION

By W. B. Russell, Published in October Proceedings

Prof. Gaetano Lanza That the apprenticeship system of the New York Central Lines must accomplish a great deal of good there can be no doubt, and it may be the best that is possible in shops so organized. Whether it is conducive to retaining the best men can only be answered by a longer trial than one year.

2 It appears that the course given to the foremen is nearly identical with that given to the ordinary apprentices. For foremen who have not already covered the ground, it will doubtless be of advantage to take the course and a more efficient one will probably be necessary for those that have completed it.

3 It is evident that the education given to any class of men, should be the best for that class, and not that of some other class.

4 It is my belief that apprentices who have had a good course in the mechanic arts are more useful, and advance more rapidly than those that have not had such instruction, and that they would accomplish more if they were first trained in the processes instead of working at the products that are for sale.

5 How many shops would be willing to incur the expense necessary to first giving instruction in the processes, and subsequently experience in the shop is an open question. Those pursuing such a course, would, I believe, be the gainers in the end.

6 The amount of theoretical or literary instruction that can be absorbed by the boy who would usually present himself for such an apprenticeship is, moreover, small, and the course should be arranged with this fact in view. But in order to accomplish the best result, and to make him a thinking and not a rule of thumb man, the greatest care should be taken to limit what is given him to what he can do thoroughly, as there is always a strong temptation on the part of both teacher and pupil to overdo, to do more, sometimes resulting in bad mistakes.

7 When it comes to a school for foremen, the paper presented by Professor Park gives the practical results that have been obtained by a course which has been in existence for four years.

8 Another class who need a different course are the graduates of good technical schools. They are aiming to become engineers or managers. That they should perform some of the lowest grades of work, even cleaning out a smoke box, goes without saying, but the

frequency of the changes in their duties should depend upon their competency.

9 To tax their powers they should also be given problems to work out, the solution of which will give them a broader view of the departments.

10 In general, it is necessary to specify what class of men the course is intended to educate, inasmuch as a course suitable for one may not be at all suitable for another class of men.

PROF. A. L. WILLISTON It is an important step in industria education to have a large railroad company like the New York Centra undertake with thoroughness and seriousness the systematic instruction and education of the men in its large shops.

2 The various schemes for training working men presented to this Society have necessarily differed widely, for industrial education is many sided and requires many methods of approach, each one adapted to its particular set of conditions and requirements. The new movement by the New York Central Lines is one more important step toward the solving of one of the most gigantic problems that confronts our profession today.

3 One or two points are of special significance. First, those interested are able to get hold, without any question, of the right type of men to be employed in the railroad shops. In some methods there is no way of being sure of this. Young men are being educated to be machinists, but after their training is completed, it is frequently found that much of the time has been wasted, because they decide to enter some other occupation. In the plan described this question is entirely eliminated.

4 The second point is the perplexing problem of providing some means of support for the young men during the period of training. By this plan men receive their regular pay as full time apprentices, which is sufficient for them to live upon. This is most important, as the young men who actually go into the machinist's trade generally come from homes from which they can expect but little or no financial support. Consequently any plan for training machinists must, if it is to succeed, include some such provision.

5 The third point is that the company's time is used for educating these young men in class rooms with trained and paid teachers who are especially chosen because of their particular fitness and who are expected to develop courses of instruction that will accurately fit the needs of men in each of the shops. The teachers have had similar

experience; they thoroughly understand the conditions, and have every opportunity for making the work thoroughly practical.

6 The very best hours in the day and in the week are chosen. In no better way could the company say to its men that they regard it of more importance for them to learn, if any difference is to be made, than to work.

7 In the many systems that have been heretofore suggested, the time for education has been limited to six months or a year, or other comparatively short periods. In this system the instruction is distributed over four years. In four years, with five hours of regular instruction each week, a great deal can be accomplished, more than could be done with the same number of hours concentrated into a shorter space of time.

8 The system described has many excellent points. In the classroom there is developed an atmosphere of inquiry and ambition which ought to stimulate the men to do their very best and arouse high ideals; and in the shops there is a special instructor whose duty is to be ready to give individual aid wherever it will do most good; who sees that each individual gets as large a variety of practical experience and also profits as much as possible from each of the tasks assigned him. In such a system we expect and feel a growing coöperation between the corporation and the employees in the shops, which is decidedly increasing their efficiency.

9 It will doubtless take time to develop the courses of instruction to fit best the needs of those for whom they are intended; it will take time to find and train the men who will make the most efficient instructors; but gradually these difficulties may be overcome. In one or two other particulars, too, the work may be somewhat handicapped. Usually young men attend trade schools, from a desire to learn and because they feel the need of the training. In the plan described they go because the rules of the shop require it. In many trade schools, drawing their students from the whole of a large community, it is often possible to get a body of young men far above the average in intelligence and in ambition. Here such a picked body of young men is impossible. The railroad must deal with the rank and file of those who enter its employ.

10 These are a few of the difficulties that must be met. Another is that the shop and the class instructors, surrounded as they always must be by the big commercial organization, will find it difficult to create among the young men who are under their charge quite the same kind

of *esprit de corps*, that they would be able to obtain from their students if they were somewhat less dominated by the commercial atmosphere of the shop. In spite of these difficulties, however, the plan which Mr. Russell describes in his paper has many good points in its favor, and very far reaching possibilities of application.

MR. H. F. J. PORTER This paper is really an appeal for the education of the manager; of all officials from the president down.

2 The paper and the discussion emphasize the necessity of securing the loyalty of the organization. This loyalty cannot be elicited unless the management inspires confidence by assurance of fair treatment and reasonably steady work. There is no use in educating the employee if at the first sign of a financial flurry the works are shut down or the payroll materially cut.

3 Notwithstanding the establishment by colleges and technical schools of courses in economic methods of organization and management in response to the urgent demand for men to take control of industrial enterprises, there is still a crying need for the broad dissimilation of a knowledge of business principles.

4 From time to time suggestions have been made, looking toward the establishment of a national society of business managers. Perhaps this period of suffering due to the bad business methods of the managers of large corporations, may be found the psychological moment for inaugurating such an association.

MR. FREDERICK A. WALDRON It would seem that an apprenticeship is the same to a young mechanic as the college course is to the engineer; it teaches the young man how to learn. Does not the greatest scope of industrial education lie in the broadening out of the apprentice, journeyman, foreman and superintendent along those lines which will compel him to consider manufacturing *as a business* and not as an aggregation of technical or mechanical problems alone?

2 The young industries of this nation may well profit from the thoroughness of the older nations, who carefully consider the minutest detail. Impress upon the young man the value of detail.

3 The watchword of the apprenticeship training system should be thoroughness rather than speed. Teach thoroughness at the start and speed afterward. This can only be done by a sufficient number of competent instructors placed over a limited number of apprentices. Methods of handling tools and machines and the reasons therefor

should be carefully taught. Passing through the shops of a concern having a very complete apprenticeship system, the fact that impressed the writer most was that very few of the apprentices could take hold of a file and manipulate it in the proper manner. Upon inquiry it was found that they had never received thorough detailed instruction in the use of a file, either at the bench or lathe.

4 I do not agree with the statement made in paragraph 6 of Mr. Gantt's discussion, in which he quotes Mr. Basford as saying, "The captain and subordinate officers will not constitute a problem." This will ever be a problem, as the personal equation cannot be eliminated, and the personality of the leader inspires the rank and file with confidence which begets enthusiasm, and without the latter the highest efficiency cannot be obtained.

5 It is equally important that shop ethics should be thoroughly taught the apprentice. He should be trained to a sense of honor and a standard of personnel so high that those entering the course have not only the desire to be good mechanics but broad, upright, honest and high-minded men.

6 By beginning along these lines a desire is created for a broader standard of manhood, and duplicity, politics and petty jealousies will almost disappear.

Mr. W. J. Keep A broad and successful work covering so wide a range as that of the New York Central Lines, where the elevation of 6000 or 7000 men is involved, is worthy of the support of all men. At the same time it is too much specialized to meet all of the demands for industrial education.

2 The ideal system is one which develops the man as a *man* and not as a *machine*.

3 To train a man under the same system and in the same atmosphere in which he spends his working hours is not an easy thing to accomplish. You may be able to increase his earning capacity, but the largest growth and the best results do not come from putting the men in competition with each other. The writer has found that we must first put the man in competition with himself.

4 This requires (*a*) an inspired teacher who can create inspiration through his complete knowledge of the intent of the course, through his control of men and through intimate contact with the students; and (*b*) an opportunity for the man to "try himself out," unhampered by any suspicion that he is not getting a "square deal."

5 We must return to our former ideals; turn the trade schools back toward their original purpose, individualize the students of our apprentice schools and give them confidence in themselves and pride in their work and their loyalty.

6 The New York Central Lines in their own way—philanthropic, magnificent—are sacrificing 30 000 or 35 000 hours a week in the cause of pure education. Other companies are experimenting with other apprenticeship courses. All have the same end in view, but, of necessity, too much attention is paid to specialization. The supply is far too limited, and the field covered too narrow to meet the general demand. What is needed is an industrial educational system devoid of specialization.

MR. OSCAR E. PERRIGO The writer heartily approves of this apprenticeship plan and recognizes that it is the result of much study and experience by men eminently qualified for the work.

2 The apprenticeship contract for a four year's course should contain a provision whereby the bright and active apprentice may, by exceptionally good work, shorten this period to three years. The following plan is suggested. Divide the four years' course into eight periods of six months each. Fix a rate of pay for the first period and add one cent per hour to this rate at the end of each period. The system of reports should show a percentage of efficiency for each month. The average of this percentage for the first period should determine the time to be deducted from the succeeding period as a reward, and so on through the course.

3 There might well be a provision in the contract whereby a percentage of efficiency below a certain point would lengthen the regular term of four years. But practical shop men are likely to reply to this that the apprentice who cannot learn the trade in four years might as well be dropped from the roll.

4 In the practical work of the shop it is often found that one of the most difficult things for the technical college graduate to do is to *think outside of the book*. It is just here that the system formulated by Mr. Cross and Mr. Russell attains its greatest and most useful result. Text books are cast aside, and the apprentice is taught in a practical way *to do his own thinking*.

5 The shop instructor, directing the practical education, the educational instructor, teaching technical matters in simple every day language without reference to texts books, and the shop foreman, should

constitute a committee whose recommendations regarding the progress of the apprentice, when approved by the shop superintendent, should be final.

MR. ARTHUR L. RICE The key-note of this problem is in the last paragraph of the paper, which should have been the first one, namely, that if we are to succeed in producing a good and useful workman it is vitally necessary to aim at the development of moral character and loyalty to right. Before a full day of conscientious work is secured from the coming mechanic he must grasp the meaning of duty to himself and to his calling.

2 The courses as outlined seem to be admirable. Experience teaches that, in order to arouse the interest of the average man, it is necessary to employ practical problems. The statement of the laws governing falling bodies is of little interest; but the solving of a problem on the pile driver catches the attention at once, and brings the desire to know the principles underlying the solution.

3 In industrial education the proving of scientific laws has however, no place. The men should be taught how to use the tools of both hand and mind—not how to make the tools of either kind; and for the purpose there is quite as much of educational value in the using of the tools as in the making of them; as much in the solving of the steam engine problems or the setting up of a gear-cutting machine, as in proving the laws of thermodynamics or of kinematics.

4 Instead of text books is to be recommended the study of technical journals and mimeographed or printed instruction leaflets, as the best means of keeping abreast of the progress of the art.

5 The value of a technical education from a dollars and cents standpoint is unquestionably proved; but so far as the economic problem goes, we have yet to adapt our means to the end so that there shall be the least loss of time and money to the individual and the community. Putting six years of preparatory and engineering college training on a boy who wants to be and is fitted by nature to be a department foreman, does not agree with our ideas of commercial efficiency; and, though we may have made a somewhat better citizen, it is questionable whether the really usable amount of training in technical matters, supplemented by greater attention to business methods, the laws of economics, and the principles of good government would not make a broader minded and more efficient shop superintendent than even the best of our engineering college courses.

A HIGH SPEED ELEVATOR

By Charles R. Pratt, Published in October Proceedings

The Author To the discussions both for and against this *positive control*, the author concedes, that aside from requirements of safety alone, his paper predicted results of minor importance and which are subject to experiments. This closure will show how the safety functions can be obtained in a perfectly simple and reliable way, with no possible interference with the present functions of this elevator, and with no material loss in efficiency:

2 The author's efforts to introduce this present method of traction rope drive have been, namely,

1891 Designed one for a 1000-foot tower, intended for the Chicago World's Fair, but not erected.
1896 Advised it for the Park Row Building, New York.
1899 Paper on "Elevators" in Transactions, vol. 20, p. 826.
1899 Advised the Otis Elevator Company to use it.
1902 Built one for the Marine Engine and Machine Company.

3 While there is some satisfaction in anticipating by over 14 years, a method so obvious that it should have been accepted at the first suggestion, it is not so satisfactory to see history repeat itself by rejecting another suggestion equally obvious, important and logical.

4 There are members of our Society and other engineers who will read this paper, who know that this new traction elevator has lowered the old standard of safety, and who are in a position to have this grave error rectified. To such engineers I present the following statement of one way in which this elevator can be *positively controlled*.

5 This description relates only to conditions of safety. The predictions for increase of efficiency, improved acceleration, etc., in this paper, as published in the October Proceedings, will be omitted in the revised copy in the Transactions, not that they can not be obtained, but because they are of less importance, and have been used to obscure and confuse the real issue of safety.

6 Description of Fig. 1: *1* Main armature shaft. *2* Bearings for main armature shaft. *3* Main hoisting motor, about 50 horse power. *4* Traction driving sheave. *5* Hoisting ropes. *6* Elevator car. *7* Idler sheave. *8* Counterweight. *9* Low pitch worm gear. *10* Low pitch worm. *11* Worm shaft and armature shaft of motor *12*. *12* Controlling motor, one to five horse power. *13* Tail ropes or chains, to compensate for variable effect of ropes *5*.

7 Motor *3*, shunt wound, speed variation not over 10 per cent with varying loads, acts as motor to hoist and as generator to lower. About 50 horse power at 60 revolutions per minute.

8 Motor *12*, compound wound, speed variation 20 per cent with varying loads, acts as motor all the time. Uses about one horse power to drive worm *10* practically free at 1200 revolutions per minute.

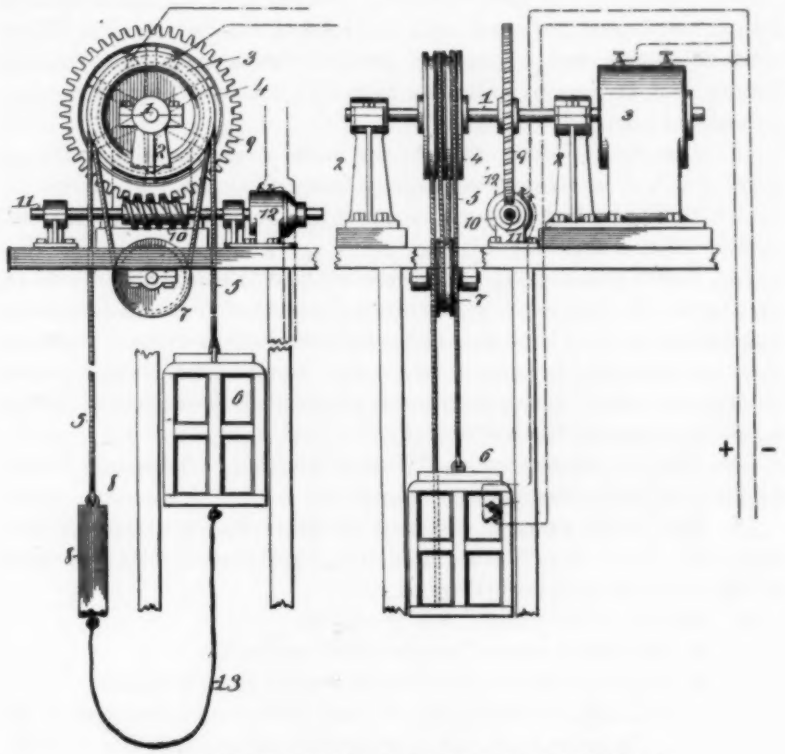

FIG. 1 SAFETY DEVICE DESCRIBED IN PARAGRAPH 6

9 Worm gear *9*, one-half the diameter of traction sheave *4*, teeth cut in bronze ring bolted to flange cast on sheave *4*.

10 Worm *10*, double thread 3 inches lead, 6 inches diameter at pitch line, thrust taken on friction washers 7 inches diameter, casing for worm and gear keeping worm submerged in oil as usual; 1200 revolutions per minute of worm follows the car at 600 feet per minute. This worm gear will hold ten times the maximum net load, the worm

can not be driven by the gear, it transmits only about 1 horse power but is of the same dimensions and speed generally used to transmit up to 25 horse power . It will show no material wear in 100 years, and always run cool. Are there any objections to this worm gear?

11 Hoisting: The circuit is closed simultaneously on both motors to hoist, the speed of motor *3* will vary about 10 per cent with the varying load, motor *12* is controlled to run at slightly relatively higher speed than the highest speed of motor *3*, but being compound wound for 20 per cent speed variation with the load, it can be retarded 10 per cent or 15 per cent by motor *3* without excess of current. About 30 per cent of current taken by motor *12* relieves motor *3* of that amount of load.

12 Lowering: Motor *12* acts the same as in hoisting, trying to drive motor *3* as a generator slightly faster than the load drives it, returning to the line through motor *3*, 30 per cent of the current that it takes from the line.

13 Worm gear action: In whichever direction worm *10* starts to drive gear *9*, it maintains its pressure on the teeth of gear *9* in that same direction from start to stop. But when motor *3* has come to nearly a stop, motor *12*, either by dynamic action, small friction brake or open circuit, comes to a full stop, and worm *10* positively locks gear *9*, sheave *4* and car *6* against further motion.

14 Thus in the normal operation of hoisting or lowering, motor *12* can do nothing else but drive motor *3*.

15 But in the event of accident to either motor, failure of current, etc., worm *10* will either hold gear *9* stationary, stop it or keep it from exceeding its normal speed.

16 Result of short-circuiting motor *12:*

a Its fuse or circuit breaker opens to the line.

b Its armature continues to revolve by its momentum.

c If its shunt field is open, it starts to generate current through its series field, but *reversing* the direction of the current, demagnetizing and building up a new field, and a weak field at that, as it is only about one-fourth compounded. If its shunt field is not opened, then the shunt and series fields oppose each other, and no dynamic action can occur to stop motor *12*. Where does the danger lie in a short circuit?

17 The increased efficiency, improved motion, simplified and more reliable control predicted in my original paper, are not important to this elevator at present. It is simply a question of this one

element of safety, namely, all other standard passenger elevators have had a *positive* resistance to the action of gravity, while this elevator *has no positive resistance* to the action of gravity. And by *positive* resistance I mean a resistance to acceleration by gravity that can not be overcome by anything short of the actual breakage of parts; and the usual least factor of safety of 8 makes breakage of any part a remote possibility, as the record of safety in the past is the best evidence.

18 It is a serious matter for any elevator manufacturer to depart from this standard of safety, inviting people to ride on elevators in which the disturbance of an electric circuit leaves nothing but the inertia of the moving mass to retard the acceleration, and automatic devices which have no *positive* action to check excess of speed. No economy of operation or any other consideration whatever can justify this risk.

19 The means that I have described provide this elevator with a *positive* resistance to the action of gravity, at no material loss in efficiency, with no change whatever in the functions and control of this elevator as it is now made, and at no material increase in cost, weight or size. It can be attached to existing elevators of this type.

20 The responsibility for the safety of passenger elevators rests as much on the engineers representing the owners of the buildings where they are installed, as it does upon the manufacturer. Every one of these engineers will read this paper. I ask them personally—*You know the risk and the remedy, what are you going to do about it?*

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